

**AN EVALUATION OF ECOSYSTEM RESTORATION  
OPTIONS FOR THE  
GRAND PRAIRIE REGION OF ARKANSAS**

**A REPORT  
PREPARED FOR:**

**U.S. ARMY CORPS OF ENGINEERS  
MEMPHIS DISTRICT**

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## EXECUTIVE SUMMARY

The Grand Prairie region of east-central Arkansas is an isolated Pleistocene terrace plain within the Mississippi Alluvial Valley (MAV). The area covers ca. 900,000 acres. The top of the terrace has relatively flat topography and is underlain by thick alluvial clay soils that are highly impermeable. During the last 10,000 years, much of the Grand Prairie terrace became colonized by prairie grasslands; a markedly different vegetation community than in the surrounding MAV which was covered by forests. The unique diversity of the region, aided by a warm temperate climate, enabled the region to support a rich floral and faunal community.

Despite its diversity and unique history, the Grand Prairie region is one of the mostly highly degraded ecosystems in North America. Native habitat are largely destroyed and highly fragmented; most of the region now supports agricultural production. Dramatic changes have occurred in fundamental ecological processes of the region such as periodicity of fire, seasonal sheetflow of surface water, and overbank flooding of local streams. Additionally, pumping groundwater for agricultural production, primarily rice, has lowered the alluvial aquifer underlying the region by more than 80' and annual extractions now exceed recharge by 17%.

Despite varied interests, many groups believe that at least some restoration of the historic Grand Prairie ecosystem is desirable. This report provides an analyses of options for restoring portions of the Grand Prairie ecosystem. Objectives include: 1) synthesize information on the geology, geomorphology, and natural history of the Grand Prairie, 2) discuss how structure and function of the Grand Prairie has been altered, and 3) identify restoration approaches and ecological attributes needed to successfully restore specific habitats. For purposes of the report, we chose the mid-1800s as the benchmark for what restored system elements should contain. This "Presettlement" baseline represents the period immediately prior to significant habitation by European people and subsequent land change.

The report also considers specific restoration options within the boundary of the proposed U.S. Army Corps of Engineers (USACE) Grand Prairie Area Demonstration Project. This USACE project seeks to address water needs in the region and proposes to pump water from the White River to the region via a system of canals, streams, and pipelines. The project also proposes on-farm water conservation measures and winter flooding of harvested rice fields. If constructed, the project will potentially purchase and manage some lands specifically for restoration of native habitats.

The Presettlement Grand Prairie ecosystem evolved from Pleistocene geological events and climatic changes that occurred in the late-glacial interval be-

ginning 16,500 years before the present (BP) and in the Holocene Altithermal 4,000-8,000 BP. Prairie grassland became established during the Altithermal when the climate was relatively hot and dry. During the last 4,000 years, deciduous trees expanded their range back onto the Grand Prairie when climate moderated and drainages began to incise the region. Seven distinct vegetation associations occurred in the region at Presettlement: 1) prairie grasslands, 2) seasonal herbaceous wetlands, 3) slash shrubland, 4) savanna, 5) bottomland hardwood forest including the meandering stream environments, 6) terrace hardwood forest, and 7) upland forest. Primary factors that influenced the structure, function, and ecological processes of these habitats were the presence of periodic fire and the amount, timing, and duration of surface water.

We used historic maps and records, information on ecological associations of specific habitat types, and on-site field investigations to prepare a map of general habitat distribution we believe existed in the Grand Prairie region in the mid-1800s. These data suggest that the 900,000 acre Grand Prairie region was about 64% forested and 36% grassland (including interspersed seasonal herbaceous wetlands). Prairie grassland was confined to high terraces and was mostly on Calloway and Crowley soils. Small seasonal herbaceous wetlands were interspersed with prairie grassland on terraces and covered about 2% of the total prairie area. Slash habitats were confined to the upper reaches of drainages and probably covered <2% of the region. Bottomland hardwood forests covered about 40% of the Grand Prairie and were present along all drainages and their floodplains. Terrace hardwood forests occupied about 9% of the region in terrace flats and depressions where "islands" of forest occurred in otherwise continuous prairie. Savanna forests were confined to the transition band between forest and prairie and covered about 30,000 acres. Upland forests occupied the hills and bluffs along the northern and eastern boundaries of the region and covered about 10% of the area.

Total native habitats have declined 73.1% and 88.7% in the entire Grand Prairie and the Grand Prairie Area Demonstration Project area, respectively, between Presettlement and current periods. Prairie grasslands, seasonal herbaceous wetlands, slash, and savanna habitats all declined 95% or more in both areas. Over 83% of Presettlement bottomland hardwood forests have been cleared in the Demonstration Project area and nearly 50% of this forest type has been cleared in the entire region. Terrace hardwood forests have declined 75% and over 90% in the entire Grand Prairie and Demonstration Project areas, respectively. About 56% of upland forests have been cleared in the region. The cumulative loss of native vegetation in the Grand Prairie is among the highest loss for any ecosystem region

in North America.

Most of the native vegetation in the region has been replaced with agricultural cropland. In the Demonstration Project area, 70% of the total 363,000 acres is now cropland. Over 97% of this cropland is irrigated, mostly in a rice-soybean crop rotation. Most conversion of native habitats to agricultural cropland occurred in the early 1900s when rice was discovered to be a viable and economically valuable crop. By 1915, over 100,000 acres of rice were planted in the region and by 1930, almost all of the Presettlement prairie grassland had been converted to rice lands.

Hydrology and topography of the region changed dramatically as native habitats were converted to agricultural cropland. Today, more than 600 wells and several hundred miles of water conveyance ditches control amount and timing of water to the region. Annual pumping water from the alluvial aquifer has created a "cone-of-depression" of groundwater that is over 100' lower than in Presettlement times. Groundwater quality has declined and irrigated lands now are more alkaline than in the past. Over 300 reservoirs that cover over 15,000 acres capture and store surface water and most employ water pump-back and return systems to recapture irrigation water. Over 100 dams, weirs, siphons, and pumps divert and extract water from streams within and bordering the Grand Prairie. Flows are reduced in all streams, many now are intermittent, and winter/spring overbank flooding occurs only during large rain events. Thousands of miles of small agricultural levees are present; many sections have up to 50 miles of internal field levees. Approximately 45,000 (18%) of irrigated fields have been laser-leveled; up to 25% may be leveled within 2-3 years.

The exact number and abundance of wildlife species present in the Grand Prairie region during the Presettlement period is unknown. However, existing data and records suggest populations of almost all species endemic to the area are greatly reduced and certain species, e.g. prairie chicken and bison, are extirpated. Increased rice production in the early 1900s apparently caused numbers of certain waterfowl (especially mallards) and icterids to increase from Presettlement, but numbers of ducks have declined significantly in the last 2 decades.

Clearly, the challenges to restore portions of native habitats in the Grand Prairie region are great, but we believe many opportunities do exist. Our assessment of potential options for restoring native habitats in the Grand Prairie region is based on certain guiding principles that include: 1) asking what is the appropriate conservation objective given varying degrees of degradation of physical and process attributes, 2) seeking a "like-for-like" restoration to restore what was formerly present at a specific locations, 3) identifying both structure and function attributes that need to be re-

stored, 4) integrating landscape ecology principles into restorations that seek to restore "land mosaics" not just individual disjunct patches, 5) honestly considering practicality of restoring sites, especially where extreme degradation has occurred, 6) understanding the level of management intensity that will be required to maintain a habitat once restored, and 7) prioritizing sites relative to limitations to system functions and threats to further degradation.

Entities interested in restoring habitats in the Grand Prairie region will have different priorities and objectives for specific locations and habitats. This document cannot decide those priorities, but we identify landscape and ecological characteristics that are needed at a site to successfully restore specific habitats. We encourage restoration of prairie grasslands on Crowley soils above 210', at least 100 acres/patch, within 2-3 miles or to connect another patch, not on laser-leveled fields, and where patches can be actively managed with fire or other disturbance. The best locations to restore seasonal herbaceous wetlands include small depressions in the prairie terrace, areas that are not heavily dissected by ditches and levees, and in former meander scars of the Arkansas River. Restoration of slash is best suited for upper ends of drainages that extend into higher elevation terraces, in lands that border drainages and field edges, and where surface water can be routed through drainages. The best restoration sites for savanna appear to be on Stuttgart, Calloway, Loring, and Calhoun soils with 1-3% slopes, near the edges of towns or farmsteads, and at the ecotone of former prairie grasslands. Upland forests are less degraded than other habitats and may be easier to restore on sites that have substantial topographic relief including edges of floodplains, adjacent to existing blocks of upland forest and on CRP lands. We encourage restoration of bottomland and terrace hardwood forests within floodplains of all regional streams, adjacent to existing patches of similar forest, in Tichnor soils, where surface water is present (or can be provided) for extended periods during winter and spring, in small watersheds that have few ditches and roads, and in historic prairie terrace flats and depressions that have not been laser-leveled.

Several options seem available to restore native habitats in areas associated with the proposed Grand Prairie Area Demonstration Project. About 184 miles of earthen canals are proposed to be built; collectively the land area included in the canal rights-of-way would be about 3,000 acres. We believe restoration of prairie grassland on right-of-way lands is possible, especially in areas where prairie previously occurred. Where grassland is planted, however, it will need to be periodically disturbed by fire or mowing. If possible, the best scenario for canal rights-of-way would be to widen the rights-of-way wherever possible to facilitate res-

toration of all native habitats that previously occurred in a location including slash and forest. Construction of additional on-farm reservoirs, especially, in non-cropland locations, is not helpful to restoration, or protection, of native habitats. Nonetheless, reservoirs can provide certain resource values if managed properly. Management plans that provide both irrigation and wildlife needs for reservoirs must be developed carefully.

The Demonstration Project proposes to incorporate existing streams into irrigation water distribution systems. Increased water retention and flow in streams provides some opportunities for enhancement of bottomland hardwood forests in floodplains. Benefits depend, however, on when the water is present, how long and deep inundation or flooding occurs, and how flows are restricted by weirs. If the Project can emulate natural water regimes and restore some winter flooding, then restoration of the most important ecological process in bottomland hardwood forests may be possible. Certain aspects of on-farm conservation measures may assist habitat restoration efforts, while others will have negative effects. Fundamentally, water conservation measures that prevent further depletion of the alluvial aquifer and the subsurface water levels and connection to the adjacent White River floodplain is desirable. The ultimate success of restoring bottomland forests in the Grand Prairie depends on restoring and maintaining seasonal water regimes in drainages of the region, including the White River. One potential opportunity associated with new tailwater ditches and control structures would be the concurrent construction of off-channel basins that could be restored to seasonal herbaceous wetlands.

The Demonstration Project proposes to provide water to flood up to 38,529 acres of harvested cropland, mostly rice, in winter. If no negative effect occurs from redistributing winter water from the White River, then adding new winter water to the Grand Prairie emulates natural flood events and is helpful to restoration efforts and supplements resources available on agricultural land. Alternately to using this water to only flood harvested fields, we suggest that some water be routed to flats, depressions, and streams in winter to encourage modest overbank flooding and to assist restoration of bottomland hardwood forests. It seems possible that a "conjunctive" use might be possible, where water is first routed to agricultural fields and then subsequently moved to drainages.

## INTRODUCTION

The Grand Prairie region of east-central Arkansas is an isolated Pleistocene terrace plain within the MAV. Most geographers define the area as being bounded by the White River on the east, the Arkansas River on the

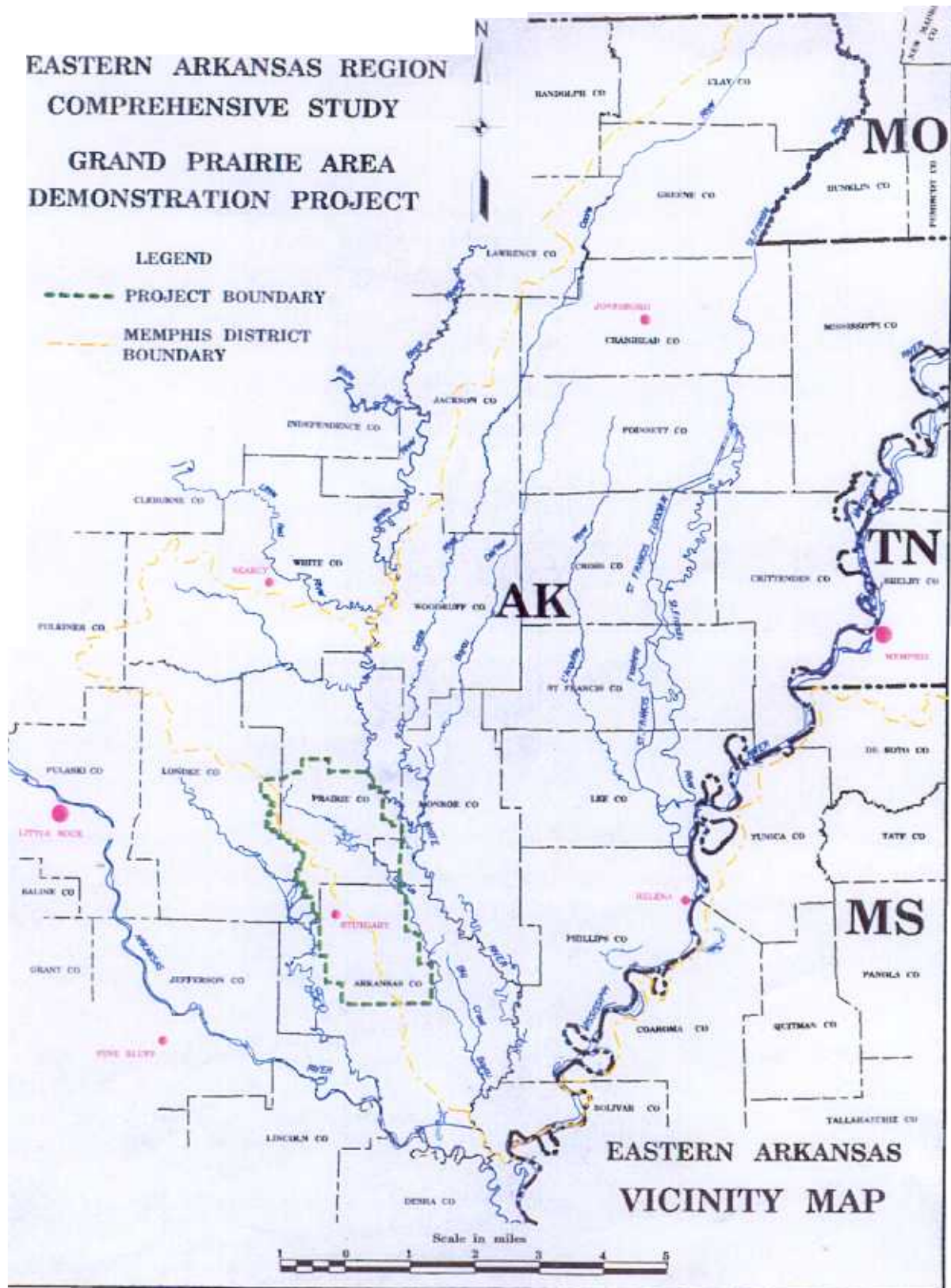
south, Bayou Meto on the west, and Wattensaw Bayou and the Interior Highlands on the north (Fig. 1). This area covers ca. 900,000 acres. The top of the terrace has relatively flat topography, is dissected by several shallow drainages, and is underlain by thick (up to 100') alluvial clay soils that are highly impermeable. During the last 8,000-10,000 years much of the Grand Prairie terrace plain became colonized by prairie-associated vegetation; a markedly different vegetation community than in the surrounding MAV which was covered by forests.

The prairie grasslands of the Grand Prairie likely represent an extension of more southerly coastal prairies. These discontinuous, relatively "wet," prairies extended to the northwestern edge of the Gulf Coast (Fig. 2) and were interspersed with bottomland and terrace hardwood forests in the MAV. This heterogeneous landscape of the MAV and Gulf Coast, aided by a warm temperate climate, enabled the region to support high primary and secondary productivity and one of the most biodiverse floral and faunal communities in North America. The Grand Prairie region has many significant local ecological values and also contributes to numerous ecological values and processes at broader regional and continental scales (Table 1).

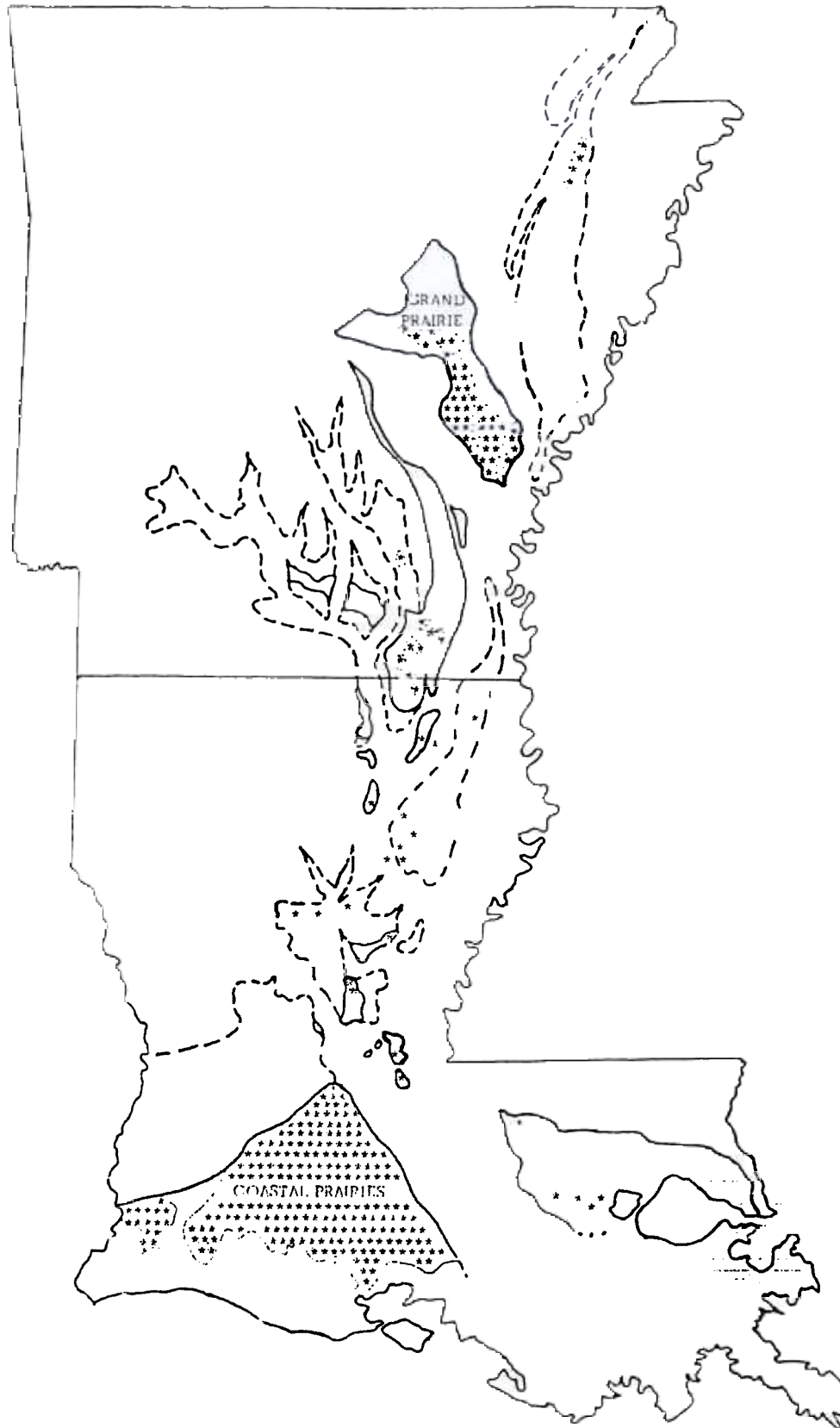
Despite its rich history and ecological values, the Grand Prairie region is one of the most highly degraded ecosystems in North America. Native habitats have declined by over 88% since the mid 1800s and remnants are highly fragmented. Dramatic changes have occurred in fundamental ecological processes such as periodicity of fire, seasonal sheetflow of surface water, and overbank flooding of local streams. Additionally, pumping groundwater for agricultural production, primarily rice, has lowered the alluvial aquifer underlying the Grand Prairie by more than 80' and annual extractions exceed recharge by 17%.

Current agricultural production and certain plant and animal communities in the Grand Prairie region are trending toward serious decline-some might say collapse, because of continued alterations to both the structure and ecological processes in the ecosystem. Landscape alterations in the Grand Prairie region also are influencing ecological processes and values, agricultural production and markets, and communities at broader scales (see Table 1). This looming crisis has prompted agricultural, community, and environmental/conservation interests both in and out of the region to consider changes in land and resource use that will help sustain the people and resources of the area. Despite varied interests, many groups believe that at least some restoration of the historic ecosystem structure and processes in the Grand Prairie is desirable.

Attempts to restore parts of the Grand Prairie ecosystem will be most successful if they are "system-based" and seek to restore the fundamental ecological



**Figure 1.** Location of the Grand Prairie region of east-central Arkansas and the proposed U.S. Army Corps of Engineers Grand Prairie Demonstration Project.



**Figure 2.** Historic prairies of the south-central United States in Arkansas and Louisiana in relationship to major terraces (courtesy of T. Foti).

**TABLE 1.** Ecological functions and values (after Richardson, 1994) of the Grand Prairie ecosystem at local, regional, and continental scales.

Value	Scale	
	Local	Continental
<b>Hydrological Regimes</b>		
Groundwater recharge		++
Surface water storage	++	+
Flood control/storage	++	+
Stream flows	+++	++
Climate control	++	+
<b>Biological Productivity</b>		
Net primary production	+++	++
C storage & fixation	+++	++
Secondary production	++	+
<b>Biogeochemical Cycling/Storage</b>		
C,N,S,P transformation	+++	+
Denitrification	++	++
<b>Water Quality</b>		
Erosion/sediment control	+++	++
Nutrient release	+++	++
Filtration of chemicals	+++	++
<b>Decomposition</b>		
Carbon release	++	++
Stream detritus	+	+
Floodplain detritus	+++	++
<b>Community/Fish and Wildlife Habitat</b>		
Habitat for unique spp.	++	++
Biodiversity	+++	++
Fish/wildlife habitat	+++	+++
Timber production	++	+
Non-ag food production	++	++
Cultural resources	++	+
Medicinal	+	+
Education/research	+++	++

processes of the entire system. A system approach to restoration requires an understanding of how contemporary landscapes were formed, how they functioned prior to significant degradation, and the trends of change that began at some prior time. Restoration efforts also must recognize that ecological processes that regulated the Grand Prairie ecosystem operated at multiple geographical and temporal scales, and work must restore structure and function at the appropriate scale. For example, fire and sheetflow helped sustain the interspersed of habitats throughout the Grand Prairie, while winter overbank flooding sustained detrital-based food webs specifically in bottomland hardwood forests.

Landscapes are not static over time and the physical form, vegetation and animal communities, and ecological processes that create and maintain specific habitats change in response to geological and climatic dynamics. For example, the Grand Prairie has contained many different ecosystem types just in the last 40,000

years (Delcourt and Delcourt 1981). A decision must be made about what "benchmark" of time will be used to determine what habitats and processes are to be restored and where. This benchmark must be practical. Attempting to restore ecosystems back to conditions several hundred years ago, or prior to mostly irreversible land changes and degradations likely will fail or be impractical.

This report provides analyses of options for restoring portions of the Grand Prairie ecosystem. Objectives include:

1. Synthesize information on the geology, geomorphology, and natural history of the Grand Prairie
2. Discuss how structure and function of the Grand Prairie has been altered
3. Identify restoration approaches and ecological attributes needed to successfully restore specific habitats

For purposes of this report, we chose the mid-1800s as the benchmark for what restored system elements should contain. We clearly recognize that only parts of the Grand Prairie region can be restored to conditions present at this time, but this "Presettlement" baseline represents the period immediately prior to significant habitation by European people and subsequent land change and is a goal for restoration.

The report also specifically considers certain restoration options within the boundary of the proposed USACE Grand Prairie Area Demonstration Project (USACE 1999). If conducted, this project will potentially purchase and manage some lands specifically for restoration of native habitats.

## THE PRESETTLEMENT GRAND PRAIRIE ECOSYSTEM

### Geological History

The Grand Prairie terrace plain was created primarily during the Sangamon interglacial stage about 120,000 BP by the Mississippi and Arkansas rivers (Saucier 1994). Additional deposits occurred during interglacial Wisconsin stages. The basement structure of the region consists of Paleozoic rocks overlain by Cretaceous sediments of marine origin. Above the Cretaceous sediments are a series of Tertiary deposits in ascending order in the Midway, Wilcox, Claiborne, and Jackson groups. The depths of the undifferentiated Claiborne and Jackson groups begin at approximately 140' below the current surface. Quaternary deposits overlay the Claiborne and Jackson groups and originated from the Pleistocene and Recent periods. Lower (50-140' below surface) substratum Quaternary layers are comprised of coarse gravel and sand grading to fine sands at upper limits. The bulk of this material is likely glacial outwash laid down by braided streams during the Illinoian glacial period. Higher surface deposits (variously 25-120' deep) are relatively uniform undifferentiated backswamp fluvial deposits originating from Mississippi River backwater. A surficial layer (15-20' thick) overlays these backswamp deposits and is a broad alluvial fan of the Arkansas River that includes miles of abandoned meandering channels, natural levees, and point bar areas (Saucier 1994). Abandoned channels are incised into lower deposits and are filled with sand. Most of this alluvial fan region is covered with a veneer of wind blown silts deposited during the late Wisconsin age. A dense, hard clay "hardpan" is present at 18-24 inches below the surface and is relatively impervious to downward flow of water. The majority of the Grand Prairie is designated as "Prairie Complex" Quaternary origin, but a small area in the west central Grand Prairie is thought to be from the "Deweyville Complex" (Saucier 1994). This Deweyville Complex area is of Arkansas River, instead

of Mississippi River, origin and includes multiple fluvial environments such as point bar, backswamp, and abandoned channel. Several large abandoned channels occur northwest of Stuttgart.

Once formed by Pleistocene fluvial deposits and further shaped by wind, the Grand Prairie region was relatively flat with minor elevational gradients. As with most MAV areas west of the current Mississippi River, lands slope eastward and southeastward. Over time, a series of streams began to incise the region, and water drained southward from over 20 small watersheds (Fig. 3). Most of these drainages were not greatly entrenched until the last 2,000-4,000 years (see below), and even today most streams are shallow, wide, and often braided. Streams originating in the northwestern part of the region have greater rates-of-fall gradients because they travel farther from a high escarpment to confluence with the Arkansas River. Grand Prairie drainages flow into the White River with the exception of Bayou Two Prairie, Mill Bayou, King Bayou, and their tributaries which flow into Bayou Meto and then the Arkansas River. Currently, elevations in the region range from 220-230' above mean sea level (amsl) in the north to less than 200' amsl in southeastern floodplains. The majority of the undissected Grand Prairie has gentle land slopes at elevations 205-220' amsl. Elevation gradients are most marked along drainages, especially those in the eastern section of the region, and along bluffs of the White River south of De Valls Bluff to east of De Witt.

Surface deposits of the Grand Prairie were shaped and moved by strong northwesterly winds present in the mid-late Wisconsin glacial and interglacial stages. Soils blown from nearby uplands and water-deposited silts created a band of hills on the northern and eastern boundaries of the Grand Prairie (Fig. 4). A thin veneer of these sediments is present across most of the region. More recent winds on the prairie sculpted gentle depressions and mounds throughout the region, including numerous small "pimple mounds" which probably were formed when wind-blown sediments were deposited around clumps of vegetation, especially shrubs. Thick deposits occurred along streams, and created "bluffs" (some of which are fairly deep), especially along the White River. The combination of newly developing drainages and wind created the relatively flat, yet incised and gently rolling, Presettlement Grand Prairie topography.

Major surface soils in the Grand Prairie region today are silt loams including the Calhoun, Calloway, Crowley, Loring, Stuttgart, and Tichnor series (Fig. 5). Crowley, Calloway, and Stuttgart soils occupy most higher elevation terraces and contain a highly impermeable fragipan or other marked textural change 18-24" inches below the surface. Calhoun soils occur in larger depressions ("flats" 1-4' below the surrounding

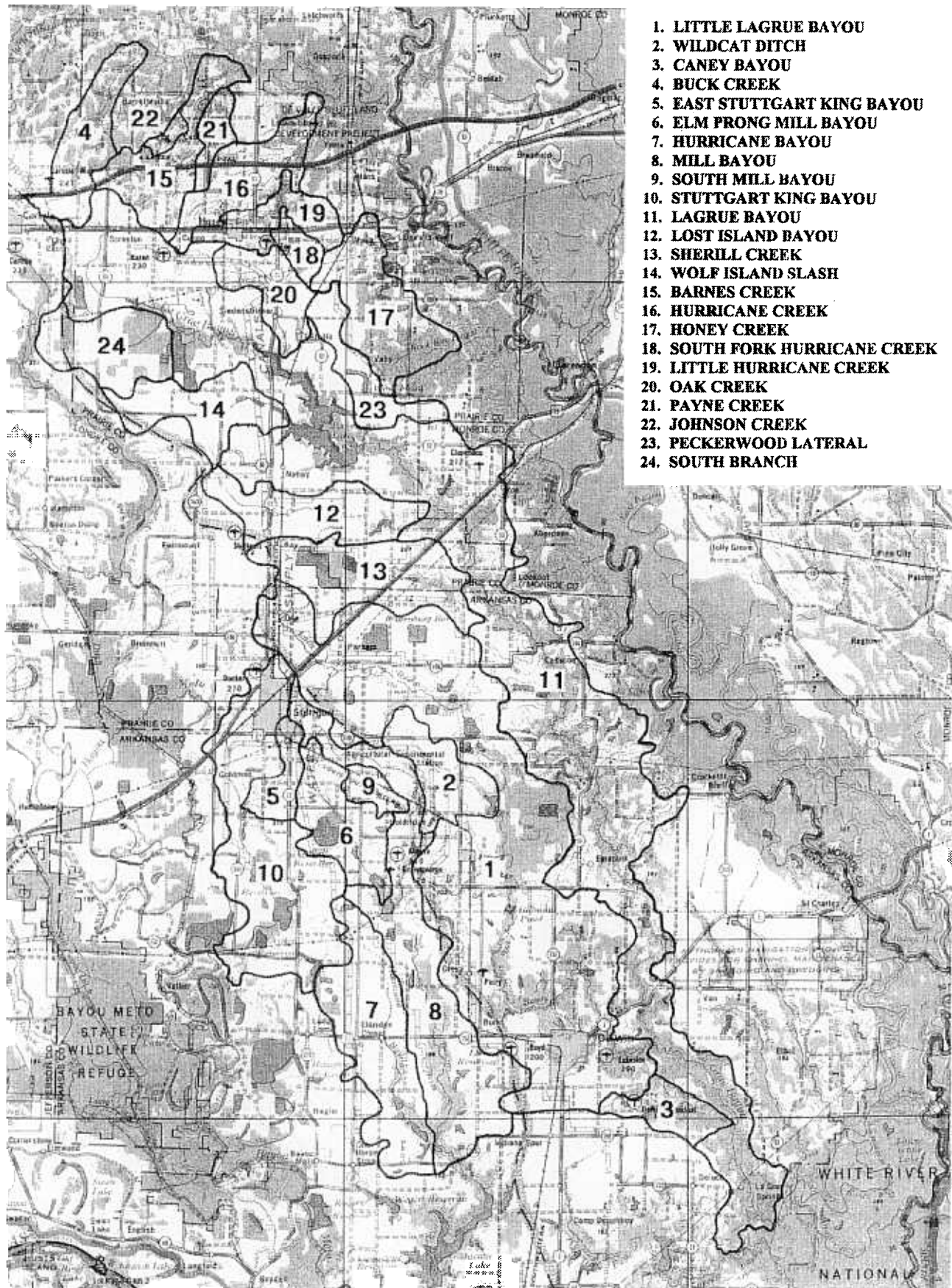


Figure 3. Primary streams and watersheds in the Grand Prairie region of Arkansas.

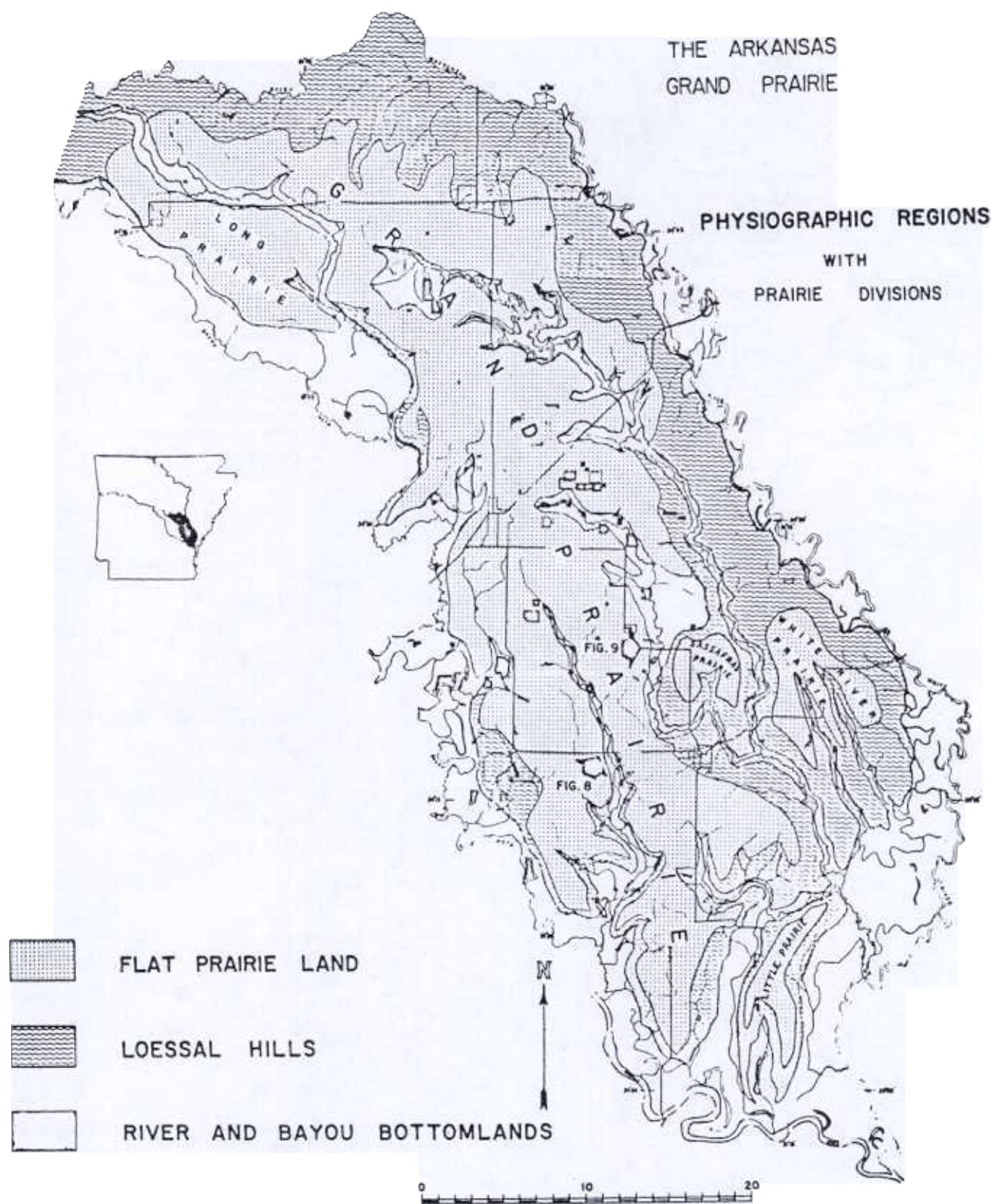


Figure 4. Physiographic regions of the Grand Prairie of Arkansas (from Corbet 1966).

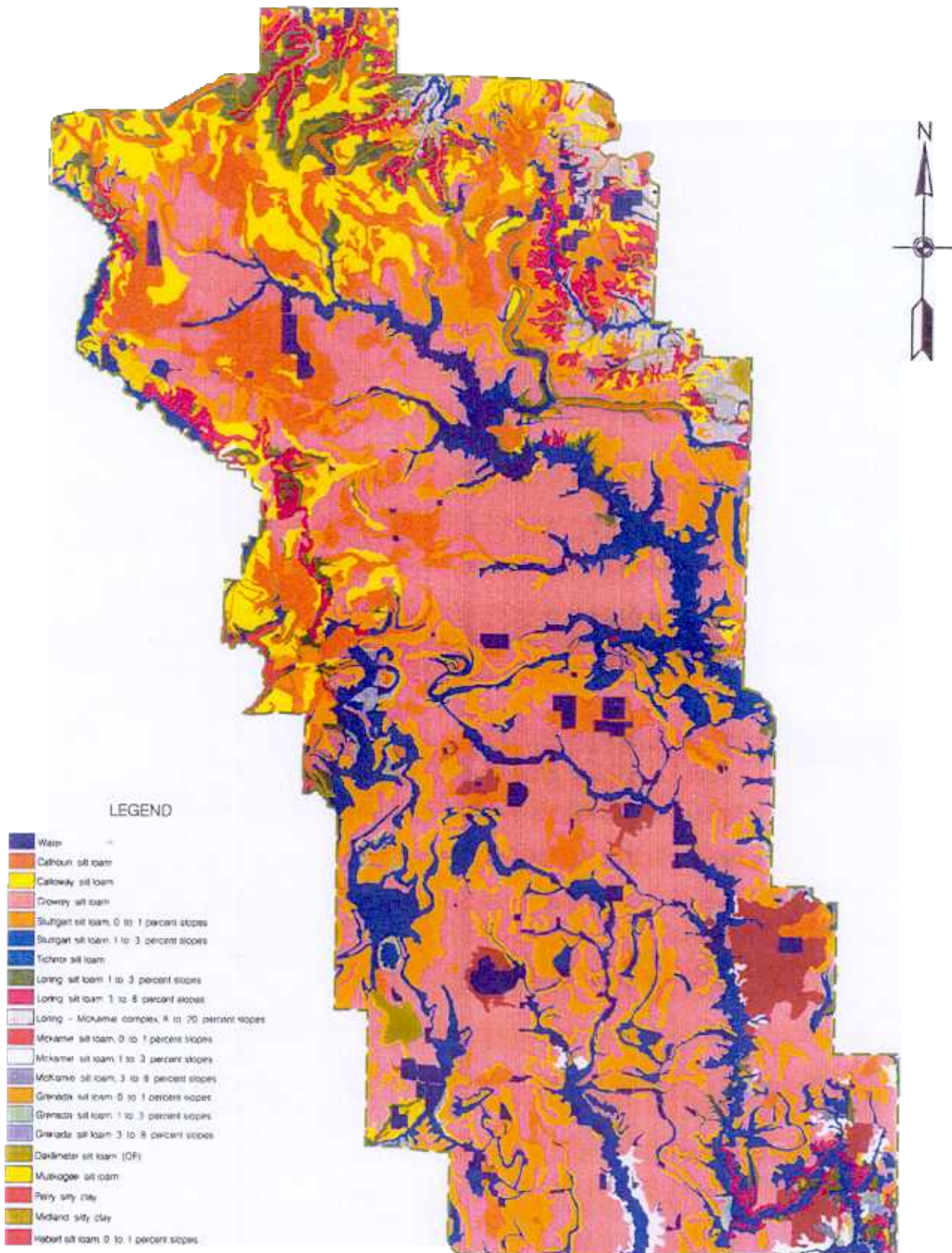


Figure 5. Soil types present in the Grand Prairie of Arkansas (from USACE 1999).

lands) within the terrace. In these flats, surface water “ponded” for longer periods and created a more saturated soil condition. Loring soils occupy transitions from flat terraces to uplands, are moderately well drained, and tend to erode quickly by surface flows. In contrast to Loring soils, some Calloway and Stuttgart soils occurred on the fringe of Crowley terraces where elevations graded into drainages and their floodplains. Tichnor soils occupy these floodplains. Minor soils include moderately well-drained Grenada soils on sloping terraces and uplands, well-drained McKamie soils in uplands, loamy Muskogee soils along the prairie fringe, and moderately well-drained Oaklimer soils in floodplains. Currently, most terrace soils have restrictive layers at 10-12 inches that have developed from long-term plowing and farming. These dense “traffic pans” limit root depth and water flow.

### Establishment of Presettlement Vegetation

The Presettlement Grand Prairie ecosystem evolved from Pleistocene geological events described above and climatic changes that occurred in the late-glacial interval beginning 16,500 BP and in the Holocene Altithermal 4,000-8,000 BP (Delcourt and Delcourt 1990). During the late Wisconsin full-glacial interval, the climate of the MAV was cool and humid and boreal coniferous forest occupied much of eastern North America north of 34°N including the Grand Prairie region (Delcourt and Delcourt 1981, Elliott-Fisk 1988). Some cool-temperate deciduous trees probably were present on hills of the northeastern Grand Prairie. Most drainages in the Grand Prairie 16,000-30,000 BP (with exception of the larger Arkansas and White rivers that bounded the region) were probably small low-gradient streams because alluvial deposits were relatively recent, the terrace topography was relatively flat, and soil erosion and runoff was moderated by dense boreal vegetation.

Climate ameliorated during the late-glacial interval beginning as early as 16,500 BP and deciduous forest trees such as oak, ash, hornbeam, and hickory replaced boreal pines, spruces, and conifers. Warm, temperate bottomland hardwood forests of oaks, sweetgum, bald cypress, and tupelogram became established throughout the MAV in the early Holocene where seasonal surface water was present in riparian corridors, floodplains, and larger depressions. Modern stream channels probably started to develop on the Grand Prairie during this period and followed topographic contours including historic river channels, cutoffs, and depositions of more easily eroded sediments. Deciduous trees probably covered much of the Grand Prairie region until ca. 8,000 BP when North American climates warmed substantially. This period of warming, referred to as the “Altithermal” or “Hypsithermal,” lasted

roughly from 4,000-8,000 BP, and was characterized by warm, dry conditions—much more so than today.

During the hot, dry Altithermal, more xeric prairie and savanna vegetation apparently spread eastward from the Great Plains (and perhaps to some degree northward from southern coastal prairie) and subsequently created a prairie-dominated vegetation community on the Grand Prairie (Wackerman 1929, Delcourt and Delcourt 1981, Axelrod 1985). Drought conditions of the Altithermal, coupled with a flat, poorly dissected topography and an impervious claypan that had developed in the region by that time, created conditions intolerable to most trees. Eventually deciduous forests retreated to wetter sites and were replaced by prairie grasses and shrubs on drier terraces. Seasonal herbaceous wetlands formed in small isolated depressions of the prairie terrace. Streams in the Grand Prairie during the Altithermal likely were poorly developed, and erosion and entrenchment were retarded because rainfall and runoff were limited. Small drainages probably did support narrow bands of riparian forest and a combination of pioneering shrub and tree species (slash). Some “savanna” forest probably was present in the ecotone between prairie and riparian areas.

After about 4,000 BP, the climate of the MAV and Grand Prairie region became more humid and warm temperate. Presettlement climatic conditions were not much different than today. Presently, average daily temperature for the Grand Prairie ranges from 43°F in January to 83°F in July (Table 2). Occasional periods of more extreme cold (0-20°F) and heat (100-110°F) occur. The frost-free period averages 200 days from early April to mid-October. Average rainfall is near 49 inches, the months of March-May are the wettest and July-October the driest. Evapotranspiration averages 52 inches annually. Snowfall is erratic, averaging 2 inches each winter, and is absent in many years.

TABLE 2. Mean monthly temperature (degree F) and precipitation (inches) for the Grand Prairie region of Arkansas.

Month	Temperature	Precipitation
January		
February		
March		
April		
May		
June		
July		
August		
September		
October		
November		
December		

During the last 4,000 years, deciduous tree species expanded their range back onto the Grand Prairie from refugia occupied in wetter and more well-drained riparian areas during the Altithermal. The expansion of forest throughout the Grand Prairie in this modern time was constrained by tight, poorly drained and "droughty" soils in higher terraces of the region and also probably was checked by annual wildfires set on the prairies by lightning and by Indian peoples (present in the region from ca. 8,000 BP to the early 1800s) to facilitate their hunting and travel (Foti 1971). Conversely, expansion of forests was promoted where drainages were cutting into the prairie terrace.

Development of the expanded, and in some cases more deeply entrenched, current drainages (Fig. 3) likely occurred from 4,000 BP to the present. In the last 4,000 years, rainfall and runoff increased in the region and subsequent erosion of prairie soils was accelerated by retreating prairie vegetation. Furthermore, increased rainfall and runoff, especially during "pulse" rainfall events increased flooding and expansion of floodplains of the larger drainages, especially La Grue, Meto, Two Prairie, and Mill bayous. Longer periods of soil saturation and regular flood events in these areas favored expansion of bottomland hardwood forest communities in floodplains and terrace hardwood forest in low flats and depressions. Savanna forests extended farther into former prairie areas, and "slash" communities occupied the upper "head cut" ends of drains at their origin in flat prairie land.

Development of vegetation and wetland "habitat types" in the Grand Prairie region in the last 2,000 years has been a gradual transition from the relatively flat and poorly drained "prairie" developed in the Altithermal to a gradually expanding bottomland hardwood forest and dissected drainage system. When European settlers moved to the region in the 1800s (Desmarais and Irving 1983), forests were expanding their range and displacing prairies (Nuttall 1821). Indian people probably influenced the rate and distribution of this transition through fires and perhaps some agriculture (Wright and Bailey 1982), but forests clearly were out competing prairie wherever seasonal surface water and drainage were present.

## Ecological Attributes and Processes of Presettlement Habitats

### General

In this report we distinguish 7 distinct vegetation associations for the Presettlement and current Grand Prairie: 1) prairie grasslands, 2) seasonal herbaceous wetlands, 3) slash shrubland, 4) savanna, 5) bottomland hardwood forest including the meandering stream environment, 6) terrace hardwood forest, and 7) upland forest. Many authors subdivide or lump certain

of these habitats, especially forest types. Forests represent composite gradations of species assemblages as elevations and soil moisture change. Specific designation of "zones" or "types" is complicated by topographic heterogeneity at local scales, past climatic dynamics, and disturbance regimes. We acknowledge the difference in opinion about which separation of forest species and elevations is ecologically significant and have chosen the above separation based on the most pronounced differences in topography and hydrology within the Grand Prairie region.

Primary factors that influenced the structure, function, and ecological "processes" of habitats in the Grand Prairie region were the presence of periodic wildfire and the amount, timing, and duration of surface water. The general climate of the region is a unique hydric-xeric condition. Annual rainfall in the region is relatively high from late winter through spring (Table 2), yet summer temperatures are hot, and annual evapotranspiration exceeds annual rainfall. Furthermore, surface water is prohibited from moving deep into soils (especially on high terraces) because of the impermeable claypan at 18-24 inches below the surface. Little interchange occurs between surface water and subsurface aquifers. Consequently, the top layers of soil in the Grand Prairie paradoxically are very wet from late fall to late spring, yet extremely dry in summer and early fall. Plant and animal communities that became established in the region (Tables 3-6) became adapted to these marked seasonal dynamics of surface and soil water which controlled the ecological processes of nutrient cycling, energy flow, and food webs.

Because of its "terrace" position, on-site rainfall provides almost all of the water input to the Grand Prairie. In Presettlement times, rainwater was unable to soak into soils beyond the impermeable claypan and it consequently "ponded" on or near the surface. Surface water flow across the landscape was slow, lateral, and dissipated by the dense litter of prairie vegetation. This pattern of slow overland "sheetflow" occasionally was more focused where greater topographic relief occurred and where shrub and forest vegetation (with shallower litter layers) were present. On the prairie terrace, shallow isolated depressions that had no drainage outlet received runoff and held surface water for up to several weeks. Seasonally flooded herbaceous wetlands formed in small depressions and terrace hardwood wetlands became established in bigger depressions that held water for extended periods (Fig. 6). If topographic "fall" was present, runoff from the prairie terraces became more focused and created the heads of streams in the region. When this fall was great enough, a "nick-point" was established and caused headward erosion and expansion of drainages into the terrace.

Where drainage occurred, water did erode surface

TABLE 3. Dominant plant species in habitats of the Grand Prairie region of Arkansas.

Habitat	Species	Common Name
Bottomland Hardwood Forest	<i>Acer negundo</i>	Box Elder
	<i>Carex</i> spp.	Sedges
	<i>Arundinaria gigantea</i>	Switch or Giant Cane
	<i>Carya aquatica</i>	Water Hickory
	<i>Carya illinoensis</i>	Pecan
	<i>Celtis laevigata</i>	Sugarberry
	<i>Cephalanthus occidentalis</i>	Buttonbush
	<i>Crataegus</i> spp.	Hawthorn
	<i>Diospyros virginiana</i>	Persimmon
	<i>Fraxinus pennsylvanica</i>	Green Ash
	<i>Gleditsia triacanthos</i>	Honey Locust
	<i>Gleditsia aquatica</i>	Water Locust
	<i>Liquidambar styraciflua</i>	Sweetgum
	<i>Nelumbo lutea</i>	Yellow-Lotus
	<i>Nyssa aquatica</i>	Water Tupelo
	<i>Quercus lyrata</i>	Overcup Oak
	<i>Quercus michauxii</i>	Swamp Chestnut Oak
	<i>Quercus nuttallii</i>	Nuttall's Oak
	<i>Quercus nigra</i>	Water Oak
	<i>Quercus palustris</i>	Pin Oak
	<i>Typha latifolia</i>	Cattail
Terrace Hardwood Forest	<i>Acer negundo</i>	Box Elder
	<i>Acer rubrum</i>	Red Maple
	<i>Carpinus caroliniana</i>	Ironwood
	<i>Carya cordiformis</i>	Bitternut Hickory
	<i>Carya texana</i>	Black Hickory
	<i>Celtis laevigata</i>	Sugarberry
	<i>Crataegus</i> spp.	Hawthorn
	<i>Diospyros virginiana</i>	Persimmon
	<i>Fraxinus pennsylvanica</i>	Green Ash
	<i>Ilex decidua</i>	Deciduous Holly
	<i>Nyssa sylvatica</i>	Black Gum
	<i>Ostrya virginiana</i>	Hop Hornbeam
	<i>Quercus marilandica</i>	Blackjack Oak
	<i>Quercus alba</i>	White Oak
	<i>Quercus falcata</i>	Southern Red Oak
	<i>Quercus lyrata</i>	Overcup Oak
	<i>Quercus nigra</i>	Water Oak
	<i>Quercus nuttallii</i>	Nuttall's Oak
	<i>Quercus palustris</i>	Pin Oak
	<i>Quercus phellos</i>	Willow Oak
	<i>Quercus stellata</i>	Post Oak
	<i>Ulmus alata</i>	Winged Elm
	<i>Ulmus americana</i>	American Elm
Prairie	<i>Agrostis hyemalis</i>	Ticklegrass
	<i>Ambrosia artemisiifolia</i>	
	<i>Andropogon gerardii</i>	Big Bluestem
	<i>Andropogon ternarius</i>	Split Beard
	<i>Andropogon virginicus</i>	Broomsedge
	<i>Aster ericoides</i>	

TABLE 3. Dominant plant species in habitats of the Grand Prairie region of Arkansas. (continued)

Habitat	Species	Common Name
Savanna	<i>Carex caroliniana</i>	
	<i>Carex hyalinolepis</i>	
	<i>Carex meadii</i>	
	<i>Carex reniformis</i>	
	<i>Castilleja coccinea</i>	Indian Paintbrush
	<i>Commandra umbellata</i>	Bastard Toadflax
	<i>Cyperus strigosus</i>	
	<i>Echinochloa colonum</i>	Jungle Rice
	<i>Echinochloa crusgalli</i>	Barnyard Grass
	<i>Eleocharis tenuis</i>	Spikerush
	var. <i>verrucosa</i>	
	<i>Eryngium yuccifolium</i>	Rattlesnake Master
	<i>Euthamia leptcephala</i>	
	<i>Fimbristylis autumnalis</i>	
	<i>Fimbristylis puberula</i>	
	var. <i>pubetula</i>	
	<i>Helenium</i> spp.	
	<i>Helianthus angustifolius</i>	Sunflower
	<i>Helianthus mollis</i>	Ashy or Hairy Sunflower
	<i>Heterotheca graminifolia</i>	Grass-leaved Golden Aster
	<i>Juncus effusus</i>	Soft Rush
	<i>Liatrus aspera</i>	Rough Blazing Star
	<i>Panicum dichotomum</i>	Fall Panicum
	<i>Panicum acuminatum</i>	Panic Grass
	<i>Panicum sphaerocarpon</i>	
	<i>Panicum virgatum</i>	Switch Grass
	<i>Parthenium integrifolium</i>	
	var. <i>hispidum</i>	
	<i>Psoralea psoralioides</i>	Sampson's Snakeroot
	var. <i>eglandulosa</i>	
	<i>Andropogon scoparium</i>	Little Bluestem
	<i>Sorghastrum nutans</i>	Indian Grass
	<i>Scelria pauciflora</i>	
	<i>Senecio tomentosus</i>	Wooly Ragwort
	<i>Solidago gigantea</i>	Goldenrod
	<i>Schrankia nuttallii</i>	Sensitive Brier
	<i>Tephrosia onobrychoides</i>	Hoary Pea
Savanna	<i>Vernonia baldwinii</i>	Ironweed
	subsp. <i>baldwinii</i>	
	<i>Diospyros virginiana</i>	Common Persimmon
	<i>Rhus copallina</i>	Sumac
Seasonal Herbaceous Wetlands	<i>Rubus glabra</i>	Bramble
	<i>Boehmeria caudense</i>	Wood Sage
	<i>Carex</i> spp.	Sedges
	<i>Cephalanthus occidentalis</i>	Buttonbush
	<i>Commelina virginica</i>	Woods Day-Flower
	<i>Diospyros virginiana</i>	Common Persimmon
	<i>Eleocharis</i> spp.	Spikerush
	<i>Ilex decidua</i>	Decidious Holly
	<i>Itea virginica</i>	Virginia Willow
	<i>Juncus</i> spp.	Rushes
	<i>Planera aquatica</i>	Water Elm

TABLE 3. Dominant plant species in habitats of the Grand Prairie region of Arkansas. (continued)

Habitat	Species	Common Name
Slash	<i>Polygonum punctatum</i>	
	<i>Quercus lyrata</i>	
	<i>Quercus michauxii</i>	
	<i>Quercus nuttallii</i>	
	<i>Quercus phellos</i>	
	<i>Sassafras albidum</i>	
	<i>Teucrium canadense</i>	
	<i>Typha latifolia</i>	
	<i>Celtis laevigata</i>	Sugarberry
	<i>Cornus foemina</i>	Stiff Dogwood
	<i>Crataegus viridis</i>	Green Hawthorn
	<i>Diospyros virginiana</i>	Common Persimmon
	<i>Fraxinus pennsylvanica</i>	Green Ash
	<i>Gleditsia aquatica</i>	Water Locust
	<i>Gleditsia triacanthos</i>	Honey Locust
	<i>Ilex decidua</i>	Decidious Holly
	<i>Liquidambar styraciflua</i>	Sweetgum
	<i>Mespilus canescens</i>	Stern's Medlar
	<i>Morus rubra</i>	Red Mulberry
	<i>Nyssa sylvatica</i>	Black Gum
	<i>Prunus</i> spp.	
	<i>Quercus falcata</i>	Southern Red Oak
	<i>Quercus lyrata</i>	Overcup Oak
	<i>Quercus marilandica</i>	Blackjack Oak
	<i>Quercus palustris</i>	Pin Oak
	<i>Quercus nigra</i>	Water Oak
	<i>Quercus stellata</i>	Post Oak
	<i>Sassafras albidum</i>	Sassafras
	<i>Ulmus</i> spp.	Elm
	<i>Quercus phellos</i>	Willow Oak
	<i>Salix nigra</i>	Black Willow
	<i>Ulmus alata</i>	Winged Elm
	<i>Ulmus americana</i>	American Elm

soils, but the relatively slow sheetflow off the prairie and underlying claypan prohibited significant downward cutting. Consequently, drainages meandered and eroded laterally instead of vertically. Soil eroded from the terrace created shallow flats and deposited sediments in streams causing them to meander and form oxbows, sloughs, and braided channels. The nature of these floodplains created conditions that allowed shallow flooding over much of the floodplain when large winter and spring rains occurred.

The Grand Prairie is underlain by a relatively large alluvial aquifer contained in the 100-150' deep Illinoian sands and gravel. However, almost no groundwater moves upward to the surface, nor does surface water move downward to recharge the aquifer, because of the impervious claypan and surficial alluvial fan that overlays deeper backswamp deposits and the aquifer.

This alluvial aquifer is connected, however, to groundwater underlying the nearby White and Arkansas river floodplains (Waldron and Anderson 1995). These surface of these floodplains (150-170' amsl) is higher than the aquifer (100-120' amsl) but subsurface water is deep under the floodplains. Historically, the alluvial aquifer recharged groundwater in the floodplains during droughts and vice versa during extended wet periods, depending on the differential water pressure gradients that created downward and lateral subsurface flow in the two areas. A second, deeper aquifer underlies the Grand Prairie in the Sparta sands of Tertiary Claiborne deposits. This aquifer is separated from the alluvial aquifer by several hundred feet and receives minimal recharge.

Hydrology in the Grand Prairie ecosystem was controlled almost entirely by surface water (rainfall and

runoff). Because water was essentially contained in the top 2' of the landscape (except in some deeper drainages of incised hills and bluffs) seasonal timing and amount of rainfall controlled which plants occurred, how and when nutrients were available to plants, and subsequently the types and timing of resources available to animals.

### Seasonal Herbaceous Wetlands

Seasonal herbaceous wetlands that historically were present on prairie terraces had small watersheds and occupied low, usually isolated depressions (Fig. 6). Certain areas that had slightly rolling terrace topography, such as the area northwest of Stuttgart, may have contained denser numbers of these wetlands. Wetland basins depended on seasonal rainfall and overland sheetflow of water for seasonal inputs of water and nutrients. Energy flow, food webs, and nutrient cycling in these depressions probably were very similar to recharge basins in the prairie pothole region (Van der Valk 1988). Plants in these basins are dominated by annual and perennial herbaceous or "moist-soil" plant species that have rapid growth and reproduction, high seed production, and that generally are adapted to irregular dynamics of flooding and drought (Table 3). Persistent seed banks of wetland plants are present in the soils of these depressions and germinate and revegetate the basin when appropriate soil temperature and moisture conditions are present. Nutrient extraction by plants and invertebrates from wetland soils is rapid and concentrated in early spring when basins become flooded. The seasonal presence of water mobilizes soil and detrital nutrients and causes large pulses of nutrient flow. Wetland-associated invertebrates respond to flooding and nutrient release, grow rapidly, and reproduce at this time.

Animals that use seasonal herbaceous wetlands rely on seasonally available vegetation (especially seeds) and invertebrates. Most animals that use these basins are migrants that are present in late-winter to spring, are relatively mobile residents that use resources in these habitats for specific annual cycle events such as prebreeding, and include many cold-blooded vertebrates that emerge and undergo annual life events in short periods when water is present (Tables 4-6). When flooded, animals remove significant biomass from the basins, but they also import recycled nutrients and help disperse seeds and small aquatic invertebrates. Immediate connectivity is not important for the function of these wetlands, but regional landscapes that contain significant numbers of these basins (such as the Presettlement Grand Prairie) have relatively high energy flow and recharge of nutrients by mobile animals and wind dispersal. Decomposition processes and "in situ" nutrient cycling is greatest when seasonal water

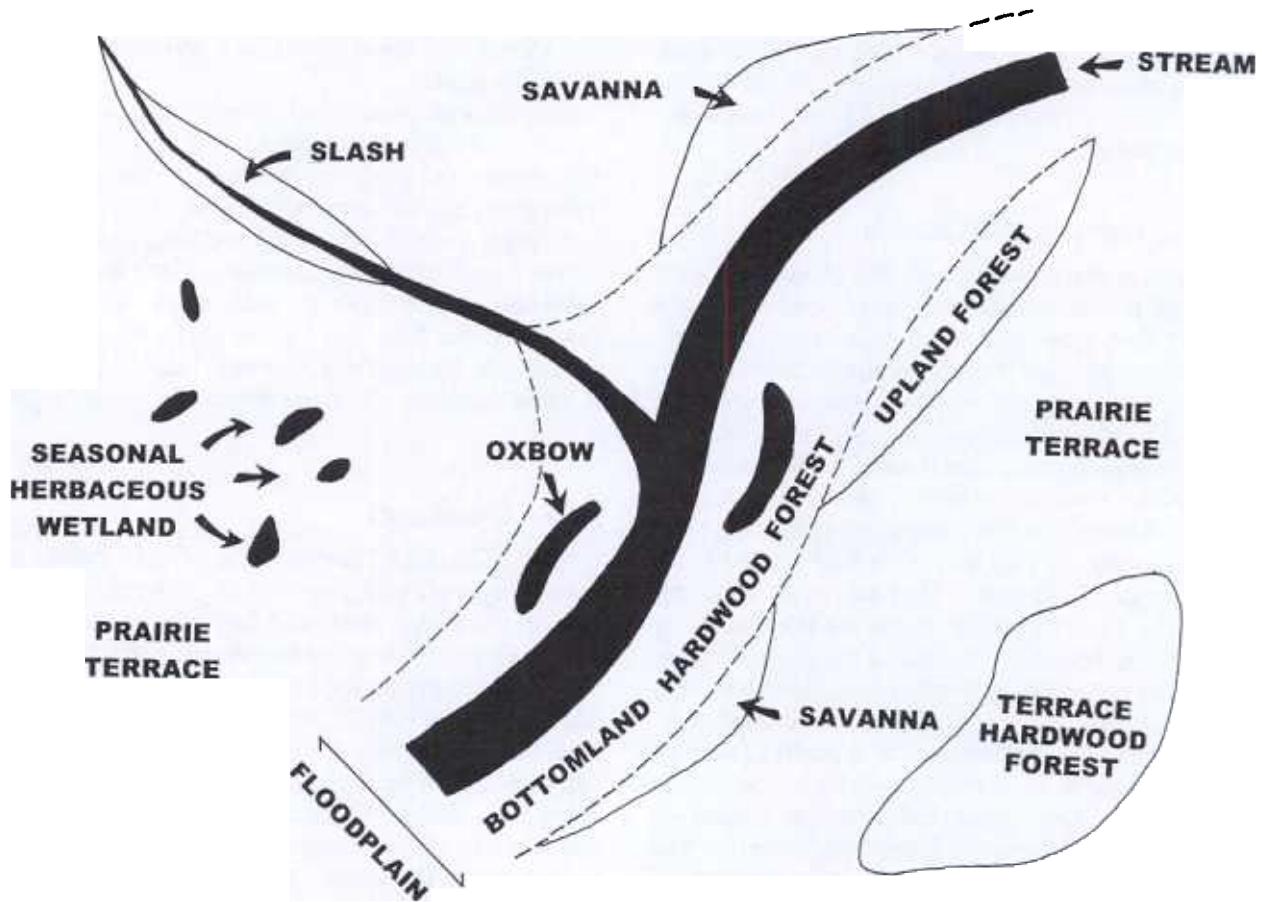
is present. At this time invertebrate populations "bloom," graze on detritus and shred organic material. Summer and fall fires in adjacent prairies occasionally spread into these basins, destroyed litter, and released nutrients.

The dynamic nature and isolation of seasonal herbaceous wetlands cause them to be fairly resilient to disturbance and fairly persistent over time so long as watersheds are not disrupted (Table 7). It is doubtful that native people influenced wetland basins much. Native people probably consumed many animals and some plants from small wetland basins and occasionally set prairie fires that burned into wetlands during dry periods. Nonetheless, we doubt that little alteration of these wetlands occurred during the Presettlement period.

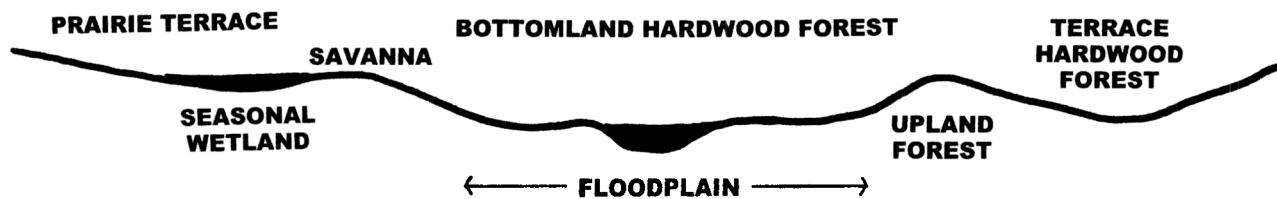
### Prairie Grasslands

Most of the high "terrace" of the Grand Prairie was covered by prairie vegetation at the Presettlement time (Fig. 6). Southern prairies in North America, including the Grand Prairie, are wetter, yet with greater extremes in wet-dry periodicity, than more northern prairies of the Great Plains (Sims 1988, Van der Valk 1988, Steinauer and Collins 1996). While species composition of southern prairies includes some water tolerant grass, forb, and shrub species, much of the structure and function of the system is similar to those found farther north. Dominant vegetation includes switchgrass, little and big bluestem, Indian grass, splitbeard, coneflower, bitterweed and scattered shrubs such as sassafras and sumac (Table 3). In this habitat, biomass, nutrient flow and cycling, and food webs are dominated by grasses and forbs (Whittaker 1975, Irving et al. 1980, Sims 1988).

In general, nutrient cycling in prairie grasslands is relatively "loose" with stocks of nutrients in the biomass small compared to that in the soil (Table 7). In the Grand Prairie, however, nutrient availability to plants and animals was confined to the top 2' of soil. Nutrient import to this prairie generally was limited to wind and animal movement into the area. Export of nutrients also was limited on the Grand Prairie terrace because of flat topography, limited drainage, and restrictive soil layers (Irving et al. 1980). Export of nutrients may have exceeded imports and the system included processes that conserved and retained nutrients. Long-term viability of the prairie ecosystem in the Grand Prairie terrace depended on low soil erosion and low modification of landscape topography, large interconnected expanses, and relatively rapid cycling of grass litter and detritus. In prairies, a high percentage of plant biomass reaches the litter each year and the return of nutrients to the soil is more rapid than in forest communities. The circulation of nutrients within prairies



### LANDSCAPE POSITION



### ELEVATIONAL CROSS-SECTION

**Figure 6.** Generalized landscape positions of the 6 primary habitat types present in the Grand Prairie of Arkansas.

**TABLE 4.** Birds present in habitats in the Grand Prairie region of Arkansas. Species were selected from range maps and habitat descriptions of several field guides. Y = Year-round resident, S = Summer, W = Winter resident, and E = Extirpated. Birds that only stop over in the Grand Prairie region during migration are excluded.

Species	Common Name	Savanna	Terrace Hardwood Forest	Bottomland Hardwood Forest <sup>2</sup>	Prairie	Seasonal Herbaceous Westlands	Slash	Upland Forest
<i>Botaurus lentiginosus</i>	American Bittern			W		W		
<i>Ixobrychus exilis</i>	Least Bittern					S		
<i>Ardea herodias</i>	Great Blue Heron			S		S		
<i>Ardea alba</i>	Great Egret			S		S		
<i>Egretta thula</i>	Snowy Egret			S		S		
<i>Egretta caerulea</i>	Little Blue Heron			S		S		
<i>Bulbulcus ibis</i>	Cattle Egret	S		S	S	S		
<i>Butorides virescens</i>	Green Heron			S		S		
<i>Nycticorax nycticorax</i>	Black-crowned Night-heron			S				
<i>Nyctanassa violacea</i>	Yellow-crowned Night-heron			S				
<i>Ictinia mississippiensis</i>	Mississippi Kite			S	S			
<i>Circus cyaneus</i>	Northern Harrier				W	W		
<i>Haliaeetus leucocephalus</i>	Bald Eagle			W (Y)				
<i>Accipiter striatus</i>	Sharp-shinned Hawk		W	W			W	W
<i>Accipiter cooperii</i>	Cooper's Hawk		W (Y)	W (Y)			W(Y)	W(Y)
<i>Buteo jamaicensis</i>	Red-tailed Hawk	Y			Y			
<i>Falco sparverius</i>	American Kestrel	Y			Y			
<i>Tympanuchus cupido</i>	Greater Prairie-Chicken				E			
<i>Meleagris gallopavo</i>	Wild Turkey		Y	Y			Y	Y
<i>Colinus virginianus</i>	Northern Bobwhite	Y	Y		Y		Y	Y
<i>Rallus elegans</i>	King Rail					S SRLr WRvr		
<i>Charadrius vociferus</i>	Killdeer				Y	Y		
<i>Scolopax minor</i>	American Woodcock			Y				
<i>Coccyzus americanus</i>	Yellow-billed Cuckoo		S	S			S	S
<i>Otus asio</i>	Eastern Screech-Owl		Y	Y			Y	Y
<i>Bubo virginianus</i>	Great Horned Owl		Y	Y			Y	Y
<i>Athene cunicularia</i>	Burrowing Owl				W			
<i>Strix varia</i>	Barred Owl		Y	Y			Y	Y
<i>Asio flammeus</i>	Short-eared Owl				W			
<i>Chordeiles minor</i>	Common Nighthawk	S			S			
<i>Archilochus colubris</i>	Ruby-throated Hummingbird	S	S	S	S	S	S	S
<i>Ceryle alcyon</i>	Belted Kingfisher			Y				
<i>Melanerpes erythrocephalus</i>	Red-headed Woodpecker	Y	Y	Y			Y	Y
<i>Melanerpes carolinus</i>	Red-bellied Woodpecker		Y	Y			Y	Y
<i>Sphyrapicus varius</i>	Yellow-bellied Sapsucker		W	W			W	W
<i>Picoides pubescens</i>	Downy Woodpecker		Y	Y			Y	Y
<i>Picoides villosus</i>	Hairy Woodpecker		Y	Y			Y	Y
<i>Colaptes auratus</i>	Northern Flicker	Y	Y	Y			Y	Y
<i>Dryocopus pileatus</i>	Pileated Woodpecker			Y				Y
<i>Contopus virens</i>	Eastern Wood-pewee		S	S			S	S
<i>Empidonax virescens</i>	Acadian Flycatcher			S				
<i>Empidonax traillii</i>	Willow Flycatcher						S(E?)	
<i>Sayornis phoebe</i>	Eastern Phoebe		Y	Y			Y	Y
<i>Myiarchus crinitus</i>	Great Crested Flycatcher		S	S			S	S
<i>Tyrannus tyrannus</i>	Eastern Kingbird	S					S	
<i>Tyrannus forficatus</i>	Scissor-tailed Flycatcher	S					S	
<i>Stelgidopteryx serripennis</i>	Northern Rough-winged Swallow	S	S	S	S	S	S	S
<i>Cyanocitta cristata</i>	Blue Jay	Y	Y	Y			Y	Y

**TABLE 4.** Birds present in habitats in the Grand Prairie region of Arkansas. Species were selected from range maps and habitat descriptions of several field guides. Y = Year-round resident, S = Summer, W = Winter resident, and E = Extirpated. Birds that only stop over in the Grand Prairie region during migration are excluded. (continued)

Species	Common Name	Savanna	Terrace Hardwood Forest	Bottomland Hardwood Forest <sup>2</sup>	Prairie	Seasonal Herbaceous Westlands	Slash	Upland Forest
<i>Corvus ossifragus</i>	Fish Crow			Y				
<i>Eremophila alpestris</i>	Horned Lark				Y			
<i>Poecile carolinensis</i>	Carolina Chickadee		Y	Y				Y
<i>Baeolophus bicolor</i>	Tufted Titmouse		Y	Y				Y
<i>Sitta carolinensis</i>	White-breasted Nuthatch		Y	Y				Y
<i>Thryothorus ludovicianus</i>	Carolina Wren		Y	Y				Y
<i>Troglodytes troglodytes</i>	Winter Wren			W				
<i>Cistothorus platensis</i>	Sedge Wren				S	S		
<i>Regulus satrapa</i>	Golden-crowned Kinglet		W	W				W
<i>Regulus calendula</i>	Ruby-crowned Kinglet		W	W				W
<i>Poliophtila caerulea</i>	Blue-gray Gnatcatcher		S	S			S	S
<i>Sialia sialis</i>	Eastern Bluebird	Y					Y	
<i>Catharus guttatus</i>	Hermit Thrush			W				W
<i>Lanius ludovicianus</i>	Loggerhead Shrike	Y					Y	
<i>Vireo griseus</i>	White-eyed Vireo	S		S			S	
<i>Vireo bellii</i>	Bell's Vireo	S					S	
<i>Anthus spinoletta</i>	Water Pipit				W			
<i>Parula americana</i>	Northern Parula		S	S				S
<i>Dendroica petechia</i>	Yellow Warbler	S		S			S	
<i>Dendroica coronata</i>	Yellow-rumped Warbler			W				
<i>Dendroica discolor</i>	Prairie Warbler	S			S		S	
<i>Setophaga ruticella</i>	American Redstart		S	S				S
<i>Protonotaria citrea</i>	Prothonotary Warbler			S				
<i>Oporonis formosus</i>	Kentucky Warbler			S				
<i>Geothlypis trichas</i>	Common Yellowthroat	S					S	
<i>Wilsonia citrina</i>	Hooded Warbler		S	S				S
<i>Icteria virens</i>	Yellow-breasted Chat	S					S	
<i>Guiraca caerulea</i>	Blue Grosbeak	S					S	
<i>Passerina cyanea</i>	Indigo Bunting	S	S	S			S	S
<i>Passerina ciris</i>	Painted Bunting	S					S	
<i>Spiza americana</i>	Dickcissel	S			S			
<i>Spizella arborea</i>	American Tree Sparrow	W			W			
<i>Spizella passerina</i>	Chipping Sparrow	Y	Y	Y			Y	Y
<i>Spizella pusilla</i>	Field Sparrow	Y	Y		Y		Y	Y
<i>Passerculus sandwichensis</i>	Savannah Sparrow				W	W		
<i>Ammodramus savannarum</i>	Grasshopper Sparrow				S			
<i>Ammodramus leconteii</i>	LeConte's Sparrow				W	W		
<i>Passerella iliaca</i>	Fox Sparrow	W	W	W			W	W
<i>Melospiza melodia</i>	Song Sparrow				W	W		
<i>Melospiza lincolnii</i>	Lincoln's Sparrow	W			W	W	W	
<i>Melospiza georgiana</i>	Swamp Sparrow	W			W	W		
<i>Zonotrichia albicollis</i>	White-throated Sparrow	W	W	W			W	W
<i>Zonotrichia leucophrys</i>	White-crowned Sparrow	W			W	W	W	
<i>Junco hyemalis</i>	Dark-eyed Junco		W	W			W	W
<i>Calcarius lapponicus</i>	Lapland Longspur				W			
<i>Sturnella magna</i>	Eastern Meadowlark				Y			
<i>Icterus spurius</i>	Orchard Oriole	S	S	S			S	S
<i>Icterus galbula</i>	Baltimore Oriole	S	S	S			S	S
<i>Carduelis tristis</i>	American Goldfinch	Y					Y	

<sup>2</sup>Bottomland hardwoods include forested habitats, oxbow lakes, swales, sloughs, and other temporary and permanently flooded habitats.

**TABLE 5.** Mammals present in habitats in the Grand Prairie region of Arkansas. Species were selected from range maps and habitat descriptions of several field guides.

Species	Common Name	Savanna	Terrace Hardwood Forest	Bottomland Hardwood Forest <sup>a</sup>	Prairie	Seasonal Herbaceous Westlands	Slash	Upland Forest
<i>Didelphis virginiana</i>	Opossum	X	X	X			X	X
<i>Blarina breviceps</i>	Short-tailed Shrew	X	X	X			X	X
<i>Cryptotis parva</i>	Least Shrew	X			X	X		
<i>Scalopus aquaticus</i>	Eastern Mole	X	X		X		X	X
<i>Myotis lucifugus</i>	Little Brown Myotis		X	X				X
<i>Myotis austroriparius</i>	Mississippi Myotis		X	X				X
<i>Lasionycteris noctivagans</i>	Silver-haired Bat		X	X				X
<i>Eptesicus fuscus</i>	Big Brown Bat		X	X			X	X
<i>Pipistrellus subblavus</i>	Eastern pipistrelle		X	X			X	X
<i>Lasiurus borealis</i>	Red Bat		X	X				X
<i>Lasiurus cinereus</i>	Hoary Bat		X	X				X
<i>Nycticeius humeralis</i>	Evening Bat		X	X			X	X
<i>Plecotus rafinesquii</i>	Rafinesque's Big-eared Bat		X	X				X
<i>Dasypus novemcinctus</i>	Armadillo	X	X	X	X		X	X
<i>Sylvilagus floridanus</i>	Eastern Cottontail	X	X	X	X		X	X
<i>Sylvilagus aquaticus</i>	Swamp Rabbit			X		X		
<i>Tamias striatus</i>	Eastern Chipmunk	X	X	X			X	X
<i>Marmota monax</i>	Woodchuck	X	X	X	X		X	X
<i>Sciurus carolinensis</i>	Eastern Gray Squirrel		X	X			X	X
<i>Sciurus niger</i>	Eastern Fox Squirrel		X	X			X	X
<i>Glaucomys volans</i>	Southern Flying Squirrel		X	X				X
<i>Geomys breviceps</i>	Plains Pocket Gopher				X			
<i>Castor canadensis</i>	American Beaver			X		X		
<i>Oryzomys palustris</i>	Marsh Rice Rat			X		X		
<i>Reithrodontomys fulvescens</i>	Fulvous Harvest Mouse	X			X			
<i>Peromyscus maniculatus</i>	Deer Mouse	X	X		X	X	X	
<i>Peromyscus leucopus</i>	White-footed Mouse	X	X	X			X	X
<i>Ochrotomys nuttalli</i>	Golden Mouse	X	X	X			X	X
<i>Peromyscus gossypinus</i>	Cotton Mouse			X			X	
<i>Sigmodon hispidus</i>	Hispid Cotton Rat	X			X	X		
<i>Neotoma floridana</i>	Eastern Woodrat			X				X
<i>Microtus ochrogaster</i>	Prairie Vole	X			X			
<i>Microtus pinetorum</i>	Woodland Vole	X	X	X			X	X
<i>Ondatra zibethicus</i>	Muskrat			X		X		
<i>Mustela frenata</i>	Long-tailed Weasel	X	X	X	X	X	X	X
<i>Mustela vison</i>	Mink			X		X		
<i>Spilogale putorius</i>	Spotted Skunk	X	X	X	X	X	X	X
<i>Mephitis mephitis</i>	Striped Skunk	X	X	X	X	X	X	X
<i>Lutra canadensis</i>	River Otter			X				
<i>Puma concolor</i> <sup>b</sup>	Panther		X	X				X
<i>Lynx rufus</i>	Bobcat	X	X	X			X	X
<i>Odocoileus hemionus</i>	White-tailed Deer	X	X	X	X	X	X	X
<i>Cervus elaphus</i> <sup>b</sup>	Elk	X	X	X	X	X	X	X
<i>Bos bison</i> <sup>b</sup>	Bison	X	X	X	X	X	X	X

<sup>a</sup>Bottomland hardwoods include forested habitats, oxbow lakes, swales, sloughs, and other temporary and permanently flooded habitats.<sup>b</sup>Historically present, currently extirpated.

**TABLE 6.** Reptiles and amphibians present in habitats of the Grand Prairie region of Arkansas. Species were selected from range maps and habitat descriptions of several field guides.

Species	Common Name	Savanna	Terrace Hardwood Forest	Bottomland Hardwood Forest <sup>a</sup>	Prairie	Seasonal Herbaceous Westlands	Slash	Upland Forest
<b>Salamanders</b>								
<i>Siren intermedia</i>	Lesser Siren			X		X		
<i>Ambystoma maculatum</i>	Spotted Salamander		X	X		X		
<i>Ambystoma opacum</i>	Marbled Salamander		X	X		X		
<i>Notophthalmus viridescens</i>	Eastern Newt		X	X		X		
<i>Ambystoma texanum</i>	Smallmouth Salamander		X	X		X		
<i>Amphiuma tridactylum</i>	Three-toed Amphiuma			X		X		
<i>Necturus maculosus</i>	Mudpuppy			X				
<b>Frogs and Toads</b>								
<i>Bufo americanus</i>	American Toad	X	X	X	X	X	X	X
<i>Bufo woodhousii</i>	Woodhouse's Toad	X	X	X	X	X	X	X
<i>Acris crepitans</i>	Northern Cricket Frog		X	X		X		X
<i>Hyla chrysoscelis</i>	Cope's Gray Treefrog			X				
<i>Hyla versicolor</i>	Common Gray Treefrog			X				
<i>Hyla avivoca</i>	Bird-voiced Treefrog		X		X			
<i>Hyla cinerea</i>	Green Treefrog		X	X		X		
<i>Pseudacris crucifer</i>	Spring Peeper		X	X	X	X		
<i>Pseudacris triseriata</i>	Upland Chorus Frog			X		X	X	X
<i>Gastrophryne carolinensis</i>	Eastern Narrowmouth Toad		X	X	X	X	X	X
<i>Rana catesbiana</i>	Bullfrog			X		X		
<i>Rana clamitans</i>	Bronze Frog			X		X		
<i>Rana utricularia</i>	Southern Leopard Frog	X	X	X	X	X		
<i>Rana palustris</i>	Pickerel Frog			X		X		
<b>Turtles</b>								
<i>Chelydra serpentina</i>	Common Snapping Turtle			X		X		
<i>Macrochelys temminickii</i>	Alligator Snapping Turtle			X		X		
<i>Kinosternon subrubrum hippocrepis</i>	Mississippi Mud Turtle			X		X		
<i>Sternotherus carinatus</i>	Razorback Musk Turtle			X		X		
<i>Chrysemys picta</i>	Painted Turtle			X		X		X
<i>Deirochelys reticularia</i>	Chicken Turtle			X		X		
<i>Graptemys kohnii</i>	Mississippi Map Turtle			X		X		
<i>Graptemys pseudogeographica</i>	False map turtle			X		X		
<i>Pseudemys concinna</i>	River Cooter			X		X		
<i>Terrapene carolina</i>	Eastern Box Turtle	X	X				X	X
<i>Terrapene ornata</i>	Ornate Box Turtle	X	X		X			
<i>Trachemys scripta elegans</i>	Red-eared slider			X		X		
<i>Apalone mutica</i>	Smooth Softshell			X		X		
<i>Apalone spinifera</i>	Spiny Softshell			X		X		
<b>Lizards</b>								
<i>Sceloporus undulatus</i>	Fence Lizard	X	X		X		X	X
<i>Eumeces fasciatus</i>	Five-lined skink	X	X	X			X	X
<i>Eumeces laticeps</i>	Five-lined skink	X	X	X			X	X
<i>Scinella lateralis</i>	Ground skink	X	X	X			X	X
<i>Cnemidophorus sexlineatus</i>	Racerunner	X	X	X			X	X
<i>Cemophora coccinea</i>	Northern Scarlet Snake					X	X	X
<i>Coluber constrictor</i>	Black Racer	X	X	X	X		X	X
<i>Diadophis punctatus</i>	Ringneck Snake	X	X		X	X		X
<i>Elaphe obsoleta</i>	Rat Snake	X	X	X	X	X	X	X

**TABLE 6.** Reptiles and amphibians present in habitats of the Grand Prairie region of Arkansas. Species were selected from range maps and habitat descriptions of several field guides. (continued)

Species	Common Name	Savanna	Terrace Hardwood Forest	Bottomland Hardwood Forest <sup>a</sup>	Prairie	Seasonal Herbaceous Wetlands	Slash	Upland Forest
<i>Farancia abacura</i>	Mud Snake			X		X		
<i>Heterodon platirhinos</i>	Eastern Hognose Snake			X		X		
<b>Snakes</b>								
<i>Lampropeltis calligaster</i>	Prairie Kingsnake	X	X		X	X	X	X
<i>Lampropeltis getula</i>	Speckled King Snake	X	X	X	X	X	X	X
<i>Lampropeltis triangulum</i>	Red Milk Snake	X	X		X			
<i>Nerodia cyclopion</i>	Mississippi Green Water Snake			X		X		
<i>Nerodia erythrogaster</i>	Yellowbelly Water Snake			X		X		
<i>Nerodia sipedon</i>	Southern Water Snake			X		X		
<i>Nerodia fasciata</i>	Broad-banded Water Snake			X		X		
<i>Nerodia rhombifer</i>	Diamond back Water Snake			X		X		
<i>Opheodrys aestivus</i>	Rough Green Snake			X		X		
<i>Regina grahamii</i>	Graham's Crayfish Snake			X		X		
<i>Storeria dekayi</i>	Brown Snake			X		X		
<i>Thamnophis sirtalis</i>	Eastern Garter Snake	X	X	X	X	X	X	X
<i>Thamnophis proximus</i>	Western Ribbon Snake			X		X		
<i>Agkistrodon contortrix</i>	Southern Copperhead		X	X			X	X
<i>Agkistrodon piscivorus</i>	Western Cottonmouth			X		X	X	
<i>Crotalus horridus</i>	Timber Rattlesnake	X	X	X	X	X	X	X
<i>Sistrurus miliarius</i>	Western Pygmy Rattlesnake	X	X	X	X	X	X	X

<sup>a</sup>Bottomland hardwoods include forested habitats, oxbow lakes, swales, sloughs, and other temporary and permanently flooded habitats.

**TABLE 7.** Ecological attributes of habitat types present in the Grand Prairie region of Arkansas.

Attribute							
Habitat	Size	Connectivity	Ratio Biomass/ Soil Nutrients		Nutrient Cycling	Persistence Resilience	Net Primary Productivity
Prairie	Large	High	Low	Med-Low	Med-Rapid	Med-Low	Med
Seasonal Herbaceous Wetland	Small	Low	Low	High	Rapid	Med-High	High
Slash	Small	Low	Med	High	Med	High	Med
Savanna	Med	Med	Med	Med	Med-Slow	Low	Med
Upland Forest	Large	High	High	Low	Slow	Med	Low
Bottomland and Terrace Forest	Large	High	High	High	Med	Med-Low	Med-High Hardwood

depends on periodic disturbances that remove and recycle litter. During the Presettlement period regular cycling of nutrients and removal of litter was facilitated primarily by fire and herbivores.

Food chains in prairies often are relatively short and driven by primary production (Whittaker 1975). However, the wet nature of the Grand Prairie may have supported greater detrital invertebrate communities and subsequently more abundant and diverse higher trophic species such as birds and small mammals than in northern prairies. While prairie grasses and shrubs may have covered much of the Grand Prairie region at its peak occurrence in the late Altithermal, this geographical region still was isolated from larger North American prairies (the closest being cross timbers and southern coastal prairies) and was comparatively small. Because of its isolation and size, the region probably did not support large numbers of resident grazing herbivores. Seasonal migration of large herbivores into the region was not common because the Grand Prairie was separated from other prairie regions by several hundred miles of surrounding uplands and forests. The primary large herbivore present in Grand Prairie grasslands during the Presettlement period was white-tailed deer which moved between forest and the edge of the prairie (Table 5). In earlier periods, elk and bison also were present in the region. Small mammals, especially herbivorous rodents, were abundant in the prairie. These rodents processed a large portion of litter and also supported many carnivores such as birds of prey, weasels, and canids. Rodent populations probably cycled with vegetation and litter dynamics as did their predators. The presence of adjoining forests provided alternate prey in years of low prairie rodent populations and probably buffered predator populations so that birds of prey and canids were always present in significant numbers.

Many birds used the Grand Prairie, and avian diversity was greater than in drier northern prairies because of its wetter nature and interspersed with forests. The bird community of the Grand Prairie contained many breeding species including prairie chickens, hawks, sparrows, dickcissel, and others that timed events to coincide with wet spring periods (Table 4). Some species, more commonly associated with wetlands, such as king and sora rail also were present (Howell 1911, Holder 1951, Meanley 1969). Drought in summer may have limited numbers and diversity of resident and breeding species, but the area attracted large numbers of wintering and spring migrant birds. The rich bird diversity, especially seasonal migrants, helped transfer energy and nutrients in and out of the system.

Generally, the prairie ecosystem had more "closed" nutrient cycling and energy flow than surrounding forests. A localized nutrient flow constrained some processes and reduced the resilience of the system to ma-

ior changes that occurred following European settlement. Its persistence also was most certainly dependent on the connectivity of the entire Grand Prairie block. When the prairie became fragmented as drainages and forests expanded and man converted prairie to cropland, the richness and viability of prairie species probably declined quickly. It also seems probable that fires were less common after Presettlement, because European settlers were more sedentary and less tolerant of widespread fires compared to native people which were transient and regularly set fires (Desmarais and Irving 1983).

### Slash

Slash habitats are present in narrow linear bands along the very upper ends of drainages that extend into the prairie terrace (Fig. 6). This site of first drainage and minor head cutting into the prairie terrace creates conditions and local sites that are better drained and with slightly longer soil moisture availability than in prairie habitats. This change allows shrubs, forbs, and some trees to invade prairie grasslands even though conditions are dry for extended periods in summer and fall. Plant species that occur in these slash areas often are highly diverse, not very abundant, contain unique species that are not found elsewhere in the Grand Prairie, and generally include pioneer species that can tolerate occasionally severe conditions. Dominant species include sugarberry, green hawthorn, stiff dogwood, deciduous holly, and American elm (Table 3). Life history strategies of plants present in slashes usually include rapid and punctuated reproductive periods, high seed production, short life spans, short and highly branched vegetative structure, wider tolerances of soil moisture and chemistry, and capability for extended dormancy.

The ecological processes of nutrient cycling and energy flow in slash habitats contain elements of both prairie and forested systems and usually include fairly rapid processing times (Table 7). Furthermore these nutrient patterns are not sustained for long periods at specific sites because the habitat itself is transitory depending on the rate of drainage expansion. At the upper beginnings of the slash, nutrients are cycled relatively quickly and exported from the site at higher rates than in adjacent grasslands. In lower reaches of a slash trees dominate vegetation and tie up nutrients for longer periods. However, trees in slashes generally are not big or long-lived and turnover is more rapid than in upland or bottomland forests. The diversity of plants, high reproductive rates, and high turnover rates created substantial energy available to higher level consumers during certain seasons. Much of this energy was in the form of seeds which helped plant species to pioneer into new areas. Detrital litter of slashes was

dynamic and probably not extensive. Consequently, detrital invertebrates in slashes were not as abundant as in forested habitats. In contrast to detrital invertebrates, insect numbers in slashes were greater than the prairies and attracted numerous insectivorous birds including flycatchers, vireos, warblers and shrikes (Table 4).

Slashes represent a transition habitat from prairie to riparian bottomland forest and their position on landscapes gradually moves headward into the prairie as head cutting and drainage increase. Habitat was constrained by fire and herbivores at the head end, yet pushed forward by encroaching bottomland forest at the lower end. Generally, slash sites were not long (less than 3-5 miles long) or connected to other slash areas on nearby drainages. The animals that used slashes represented species that are transitional between prairie and forest. Many birds used these slashes for only a portion of their life cycles, and they foraged in both prairie and bottomland forest depending on when resources were present in the respective habitats. Some unique animals, such as Willow Flycatcher, were present in slash habitats, but their populations were probably small and somewhat disjunct because the habitat itself was small, disjunct, and dynamic.

The transitory and pioneering nature of slash habitats causes them to be highly resilient to disturbances and climatic dynamics (Table 7). The system is not persistent within a specific site, but may be highly persistent within a region, albeit never very abundant anywhere. Native people probably had little influence on slash habitats, except for setting fires that set back the progression of woody vegetation. Slash habitats also may have tolerated early activities of European settlers fairly well and readily invaded sites where suitable conditions occurred following draining and clearing of the prairie.

## Savanna

Prior to settlement, the edges of prairie terraces in the Grand Prairie contained some "savanna" habitats. By ecological definition, savanna habitats contain at least 50% open grassland (Whittaker 1975). Patches of savanna in the Grand Prairie contained varying amounts of grass vs. trees depending on soils, drainage, and whether the site was on higher or lower elevations from adjacent prairie. Most savannas occurred where the prairie gradually sloped downward to drainages and bottomland or terrace hardwood forests (Fig. 6). Savannas were present in broken bands around the prairie and represented the zone of active competition between forest and prairie. Savanna areas that graded into uplands contained mostly grass (70-90%) with occasional scattered trees that were relatively tolerant of drought (Table 3). In lower sites, where drainage

was better and soil moisture was higher and more consistent, bottomland trees competed well with prairie grasses and often covered up to 50% of the savanna.

Acorns, samaras, and seeds from adjacent forests disperse into the edges (sometimes much farther) of prairies each year. The expansion of woody vegetation into grasslands is kept in check by drought, fire, herbivory, and soil composition and condition. Occasionally, seeds land in a favorable soil position in a year where more rain occurs and they germinate and survive. The intervals between favorable conditions may be long, and consequently only a few trees may survive and be present at any time. Here, a park-like condition occurs and nutrient and energy flow generally are similar to prairie grasslands. Larger savannas of the world support large numbers of grazing herbivores because of abundant food and shade. These herbivores help maintain the grassland through their herbivory, and a mutual feedback system is in effect. Savannas of the Grand Prairie were not large, but did support certain large herbivores such as white-tailed deer, elk, and bison.

Most savannas in the Grand Prairie were transition areas that contained significant amounts of post oak, hickory, ash, and elm (Table 3). Backwater flooding of savannas was rare because of their higher elevation compared to floodplains. However, the expanding drainage into the edges of the prairie terrace during the past 2,000 years created conditions where post oak and other trees were more competitive than grasses. In the more heavily wooded low savannas, ecological processes of nutrient and energy cycling were shifting from a prairie to a forested system; nutrients are bound for longer periods in woody biomass, structural heterogeneity and trophic dynamics are greater, annual net primary production is high, and detritus is processed by more rapid decomposition in a wet medium (Table 7).

In the north and east edges of the Grand Prairie, the flat prairie terrace was bounded by hills that supported upland forest. At the transition from prairie to this upland forest, savannas often were present and consisted of an interspersed of grass and trees. In these "upland-type" savannas, nutrient cycling was mixed between grasslands and upland forests. In a few cases, the savanna was actually higher in elevation than the adjacent prairie.

Animal communities in savannas include species found in both the prairie and forest (Tables 4-6). Furthermore, most animals that use savanna habitats readily move between habitat types during different seasons depending on when food, cover, nest sites, etc., are available in the respective habitats. The presence of savannas help both the prairie and forest ecosystem become more diverse and are a critical part of the function of the regional landscape. Savanna patches often are not connected, and animals that regularly use these

habitats are mobile and can move limited distances between patches. While savannas in the Grand Prairie region were not connected in large contiguous bands, their presence was dependent on the large interconnected prairie system. The location of savannas moved when upland and bottomland forests expanded into the prairie, and many species and processes are fairly resilient to disturbance and a gradual encroachment by forest (Table 7). The persistence of savannas in the Grand Prairie depended on persistence of adjacent prairie and as such is somewhat fragile and highly dependent on factors that maintain prairie topography and litter cycling. Tight claypans of the prairie terrace constrained savannas but expansion of forest promoted it; generally savannas probably were squeezed into narrow bands along this boundary of prairie and forest.

### Upland Forests

Most of the upland forest in the Grand Prairie region during Presettlement time occurred in the hills and bluffs along the northern and eastern edge of the region. Upland forest also occurred along more entrenched streams where elevation gradients were sharp between prairie terrace and adjacent floodplains. The topographic relief and loessal-type soils of bluffs and hills allowed water to run off rapidly and erode surface soils deeper than in other areas of the Grand Prairie. In comparison to bottomland and lower terrace forested areas, upland areas were not inundated by seasonal floods, nor were soils saturated for more than brief periods annually.

Where bluffs occurred along the White River floodplain, the relief from top of bluff to floodplain bottom was as much as 50-60' within a few miles, consequently the gradient of fall was substantial, and entrenchment of streams was deeper. Streams that originated in the bluffs and hills provided effective drainage of higher sites and created conditions favorable for establishment of deciduous hardwood forests dominated by oaks, ash, and hickory (Table 3). When drainages reached floodplains this upland forest graded into bottomland hardwood forest, and where hills had shallower deposits and adjoined the prairie terrace, a savanna or prairie community occurred.

The surface litter layer of upland forests is fairly thin and grades continuously from leaves to decayed particles and humus colloids to deeper soils (Greller 1988). This mixing of organic material deeper into soils is facilitated by the deeper root structure of upland trees. Active leaching of nutrients occurs downward and soils are mildly acidic and high in silica. Biomass in upland forests is high compared to prairie and savanna, but less than in bottomland or terrace hardwood forests. Likewise, detrital litter is decomposed more rapidly,

and by detrital shredders and grazers (instead of fire and herbivory in prairie and savanna), than in prairie and savanna, but not as quickly or as "tight" as in bottomland forests (Table 7). The active movement of nutrients downward into soils is countered by "pumping" of nutrients upward through deep roots of trees. This system of soil mixing and nutrient cycling creates deeper, looser soils, facilitated by the deep, usually wind blown, parent material.

Animal communities present in upland forests are more diverse than in prairie or savanna habitats yet less so than in wetlands or bottomland forests (Tables 4-6). Most species are arboreal or associated with a heterogeneous canopy layer except for larger herbivores (such as deer) and carnivores (e.g. coyote, fox, bobcat). Bird species are dominated by passerines and woodpeckers, and most species are highly insectivorous. Energy flow through the system is fairly rapid and facilitated by the generally "connected" nature of forests.

In Presettlement times, most upland forest patches of the Grand Prairie were connected to other upland forests along the White River and its tributaries northward and to adjacent upland forests of the Interior Highlands to the north and west (Holder 1951). This high connectivity provided corridors for dispersal of both plants and animals and sustained genetic diversity and high biodiversity where upland species intergrade with lowland species in the Grand Prairie region. The persistence of upland forests and their resilience to disturbance depends on maintaining a fairly delicate balance of nutrient cycling in forest soils and their watersheds. If surface water flow is accelerated or altered greatly, significant erosion occurs and nutrients are highly exported, leading to a depauperate system. Deforestation accelerates this degradation. In the Presettlement period, native people may have cleared small patches of upland forests for camps and limited agriculture, but we doubt this clearing greatly influenced drainage or plant and animal species dispersal.

### Bottomland and Terrace Hardwood Forests

Bottomland hardwood forests often are defined as the entire suite of forest types present in or near floodplains of the southeastern United States. These floodplains have seasonal inundation of surface water and extended soil saturation and contain tree and shrub species that are relatively water tolerant. Plant species composition changes in these "bottomlands" as elevation increases and soil saturation decreases from the low floodplain to higher uplands (Wharton et al. 1982). Many authors subdivide bottomland hardwood habitat types along this continuum. In this report we distinguish only between forest types that are within floodplains that regularly flood from overbank flood-

ing of rivers (bottomland hardwood) and forests present in poorly drained areas outside of floodplains such as flats and larger depressions (terrace hardwood).

While much of the basic ecology of bottomland vs. terrace hardwood forests are similar, significant hydrological differences occur between the types, and consequently the distinction is ecologically significant in the Grand Prairie region. Both bottomland and terrace hardwood forests have saturated soils for extended periods throughout the year. Bottomland hardwoods typically are seasonally inundated by floodwater (mainly backwater of streams) in most years, while terrace hardwoods seldom flood, and if they do flooding originates from high rain event headwater flow. Bottomland hardwoods have at least some drainage system interspersed through the forest while many terrace hardwood flats do not. In some locations, terrace hardwoods occur in depressions that are isolated from adjoining forests, while all bottomland hardwood forests historically were interconnected along drainages.

The presence of water and deciduous trees creates a "detrital-based" food web in bottomland and terrace hardwood forests (Wharton et al. 1982). Biomass is high in these forests and a heavy fall of leaf litter occurs annually. This litter decomposes rapidly and is aided by the seasonal flooding or saturation of litter. Inundation and saturation occur primarily during winter and spring. Winter and spring flooding supports a rich aquatic invertebrate community that processes leaf litter quickly and also is a food base for higher trophic level consumers (Table 4). Mycorrhizal fungi rapidly invade decomposing litter and recapture nutrients for a mutually beneficial plant-fungus relationship. Nutrients leached from leaf surfaces also are recaptured by an extensive network of roots and fungal filaments in the top layer of soil. This system thus has a relatively "tight" nutrient circulation that is supplemented by large inputs of nutrients when headwater and backwater flooding occur. The tight nature of nutrient flow and soil composition creates a relatively "conservative" system that is often highly disrupted when forest clearing or alteration of flooding occurs. Processing of detrital litter is more rapid in bottomland than in terrace hardwood sites, because frequency and duration of seasonal flooding is longer in bottomland hardwood floodplains.

While seasonal flooding, or extended soil saturation, is critical to the function of bottomland and terrace hardwood forests, the converse dry period of the annual cycle during summer and fall is just as important to sustaining trees because roots are not inundated during the growing season and detrital litter can be oxygenated. Trees within bottomland forests represent a continuum of species within more water tolerant species such as overcup oak and bald cypress in low, wet areas to less water tolerant species such as red oaks on

higher, drier sites (Table 3). At the upland edge of floodplains and in terrace flats tree species include hickories and more upland oaks like post oaks. The lowest areas, including remnant stream channels and sloughs, often have water present for much of the year and include diverse aquatic plants, wet shrubs like button-bush, and water tolerant trees such as bald cypress and water tupelo.

Collectively, the rich nutrient base, the great heterogeneity of plant species and vegetation layers, and the extensive and usual connectivity of bottomland and terrace hardwood forests support extensive food webs and energy flow. Bottomland and terrace hardwood forests in the Grand Prairie region represent the expanding outer edge of bottomland forests found throughout the MAV. Consequently, both plant and animal species in the Grand Prairie regularly were supplemented by species dispersing from the core of the MAV and were further enriched by unique species present in adjacent savannas, prairies, and upland forests. Most animals in bottomland and terrace hardwood forests rely, in one way or another, on the rich detrital biomass and seasonal flooding of the area (Tables 4-6). Water regimes and productivity in this system are highly dynamic, and animal species that use this habitat must be able to withstand periods of extended flooding or drying. Waterbirds are very abundant, mobile, and consume large amounts of invertebrates derived from the detritus. Some waterbirds, including the most abundant mallards and wood ducks, also have adapted to consume acorns and seeds, rootlets, or tubers of woody and shrub species present in forests. Other birds are mostly canopy or subcanopy dwellers-ground nesting species are rare. Mammals in bottomland and terrace hardwood forests are mostly arboreal species or wetland associated such as beaver, mink, muskrat, and otter. Large bodied carnivores such as red wolf and cougar were present, but populations were small and probably partly dependent on seasonal prey in adjacent habitats.

## Distribution of Presettlement Habitat Types

### General Distribution

It is difficult to know the precise distribution and composition of habitats in the Grand Prairie region during the earl to mid-1800s because few records, maps, or inventories of plants and animals are present from that time. Land and soil surveys beginning in the late 1800s and early 1900s are the best indicators of vegetation associations and distribution (e.g., Lapham 1902, Carter et al. 1906), but most accounts record only gross associations such as prairie or forest. Diaries of early settlers and visitors (e.g., Nuttall 1821) supplement early survey maps but they recorded few botanical details. Agricultural records, wildlife and habitat

cover maps, scientific literature, and aerial photographs from the 1920s-40s also document patterns and conditions of early landscapes.

We used available historic maps and records, information on ecological associations of specific habitat types (above), and on-site field investigations conducted during 2000 to prepare a map of general habitat distribution we believe existed during the early 1800s (Fig. 7). We describe gross habitat composition and distribution for the entire Grand Prairie region and provide more detailed discussion of Presettlement and current habitats for the area in the Grand Prairie Area Demonstration Project. Original plat maps of forest vs. prairie in all sections of the region are available from the Arkansas Natural Heritage Commission. It is likely that our interpretations will be further refined with future investigations and new technologies (such as tree ring and pollen analyses) that can document historical vegetation and climate patterns for the region.

Based on the above data and interpretation, the 900,000 acre Grand Prairie region was approximately 64% forested and 36% prairie grasslands (including interspersed seasonal wetlands) in the mid-1800s (Table 8). Prairie habitat was confined to high terraces and was mostly on Calloway and Crowley soils. The majority of prairie was connected in a corridor south and west of La Grue Bayou. A second corridor of prairie was present north of La Grue Bayou from Lonoke to Roe. Several disjunct patches of prairie were present south of Carlisle, northeast of Dewitt, and in the southeastern part of the region. In the mid-1800s, the smallest patch of prairie was ca. 500 acres and the largest contiguous patch was nearly 150,000 acres.

Small (usually <10 acres) isolated depressions that contained seasonal herbaceous wetlands were interspersed throughout the prairie terrace during the 1800s. Some of these seasonal wetlands apparently occurred on abandoned channels of the historic Arkansas River (see Saucier 1994). In the mid-1800s, bottomland and terrace hardwood forests and slash habitats were expanding into prairie terrace wherever surface water was present for extended periods and drainage was at least moderate. This "competition" for wetter sites was gradually being won by woody species and we do not think seasonal herbaceous wetlands covered more than 2% of the prairie area at that time.

Bottomland hardwood forests comprised about 40% of the Grand Prairie in the early 1800s and were present along all drainages and their floodplains (Table 8). Terrace hardwoods occupied about 9% of the Grand Prairie region in terrace flats and larger depressions where "islands" of forest occurred in otherwise continuous prairie. The smallest "islands" of terrace hardwood forests were about 400 acres while the largest connected corridors of bottomland hardwood forests

extended the length of the White and Arkansas rivers and along the Bayou Meto and La Grue Bayou floodplains. Other wide corridors of bottomland forests occurred along Wattensaw Bayou in the north, Two Prairie Bayou in the west, and Mill Bayou in the southwest part of the region. Bottomland and terrace hardwood forests and interspersed streams, sloughs, and oxbows occurred on Tichnor and Oaklimer floodplain soils and on Calhoun soils in broad lower terrace flats.

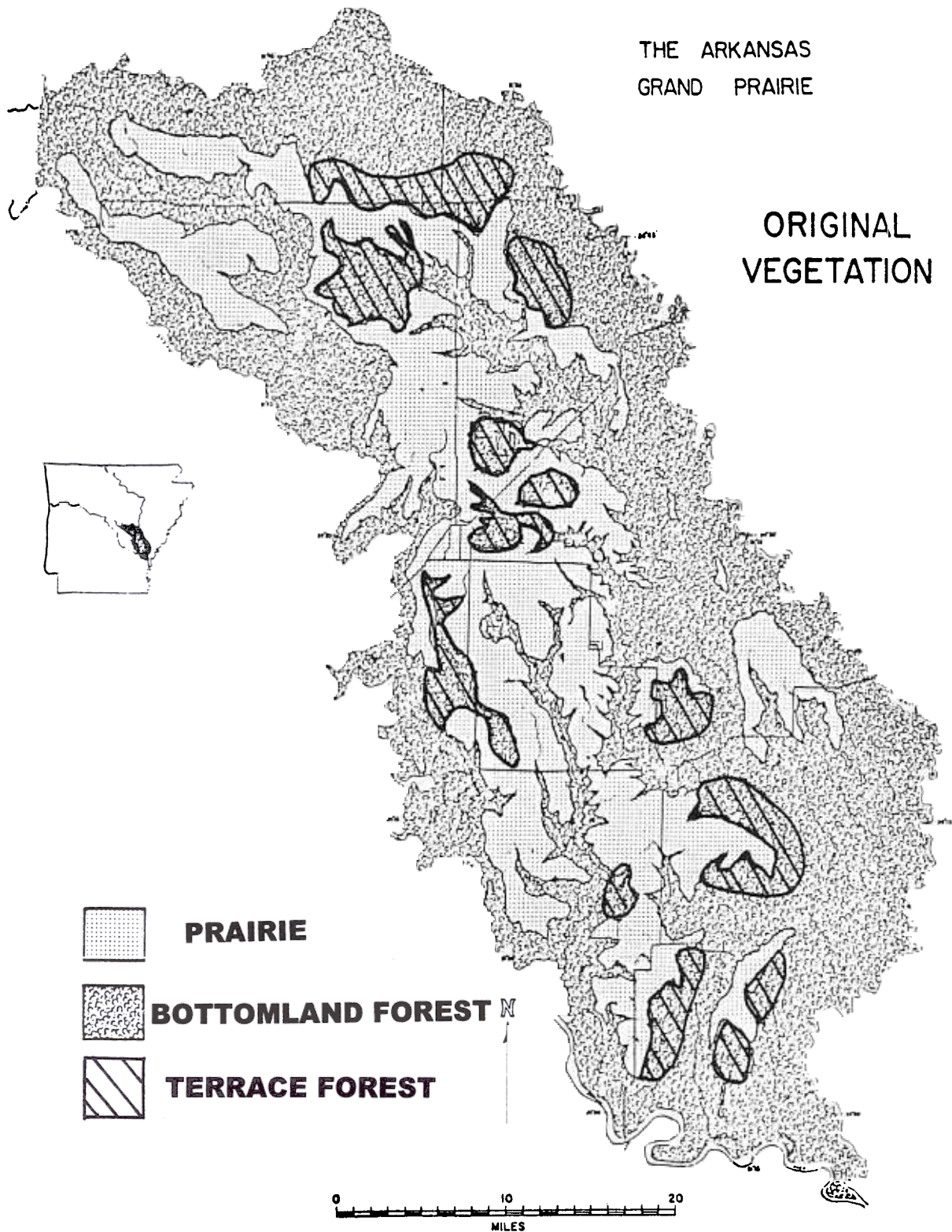
During the Presettlement period, slash habitats apparently were mostly confined to the upper reaches of Clearpoint, Hurricane, and Oak creeks and La Grue, Little La Grue, Lost Island, Wolf Island, Mill, and King bayous. Most slash areas covered less than 500 acres and many were probably only 100-200 acres. The total area covered by true slash habitat probably was <2% of the region. Slash habitats occurred in several soil types that were present at the head ends of drains including Grenada, Stuttgart, Loring, and Calloway.

Savanna habitats were confined to the transition band between forest and prairie and consequently were "squeezed" into about 30,000 acres (Table 8). The location of savannas was relatively scattered in the region; most occurred along the eastern edge of the prairie/forest ecotone. Where prairie graded into uplands, most savanna habitat occurred on Loring and some Stuttgart soils. In lower areas, savanna was present on several soil types including Stuttgart, Muskogee, and Calhoun.

Upland forests occupied much of the hills and bluffs along northern and eastern boundaries of the Grand Prairie. This area is approximately 15% of the region, but includes stream bottoms and low areas containing bottomland hardwood forests. Consequently, the area of upland forest was about 10% of the region. Most upland forests occurred on Loring, McKamie, and Grenada soils.

### Distribution by Quadrangle

We conducted field visits to the Grand Prairie during March-July 2000 to determine current vegetation associations, topographic and drainage patterns, soil distribution, and general ecological conditions within the Grand Prairie Demonstration Project area. Vegetation in the Demonstration Project area was previously mapped by the University of Memphis Ground Water Institute, and these data were used to confirm and modify maps of the current distribution of habitats. Habitat data and field visits were organized by standard 7½ minute USGS quadrangles (quads) for the region and we retain the USGS naming convention for the quads (Fig. 8). We also obtained select aerial photographs from the Slovak, Parkers Corner, Stuttgart North, Roe, and Des Arc quads from 1937 to compare



**Figure 7.** Distribution of prairie and forests in the Grand Prairie of Arkansas during the mid-1800s Presettlement period (modified from Corbet 1966).

**TABLE 8.** Acreage composition of habitats present in the entire Grand Prairie region and in the Grand Prairie Demonstration Project area during Presettlement and current periods.

Habitat	Entire Grand Prairie			Grand Prairie Project		
	Presettlement	Current	% Loss	Presettlement	Current	% Loss
	320,000	700		160,000	500	
	6,000	300	95.0	3,000	150	95.0
	16,000	400	97.5	8,000	200	97.5
	30,000	700	97.7	14,000	400	97.1
	90,000	40,000	55.6	36,000	20,000	44.4
	358,000	180,000	49.7	90,000	15,000	83.3
	80,000	20,000	75.0	52,000	5,000	90.4
	900,000	242,100	73.1	363,000	41,200	88.7

distribution of habitats present at that time with current conditions. Collectively, the field investigations, aerial photographs, ecological associations of habitats, and historical records allowed us to prepare the following analyses of vegetation associations we believe existed in the mid-1800s.

**Carlisle.** - Most of the Carlisle quad (Fig. 9) is >220' elevation and contains the highest elevations of the Grand Prairie (up to 235'). Much of the region was prairie up until the early 1900s, especially above 215-220'. Bottomland forest occurred below 215' along Two Prairie Bayou and its tributaries. Barnes Creek apparently is a fairly recent head-cutting drainage into the prairie and elevation contours along the creek are sharp. A small amount of savanna was present at the head of Buck Creek during the Presettlement period; this savanna graded into upland habitats north of the area. Slash habitats likely occurred along the upper end of La Grue Bayou west of Hanson's reservoir.

**Hazen.** - Much of the Hazen quad is highly dissected and forests covered most of the area except for terrace benches above 220' which were prairie (Fig. 10). Bottomland forest occurred below 215' along Barnes, Hurricane, and Payne creeks and Wattensaw Bayou. Terrace hardwood forest was present in the low flats near Sims Reservoir. Upland forest covered significant portions of the quad in the dissected uplands along the above drainages. Some savanna probably was present along the transition boundary from prairie to upland forest in each of these areas. A thin band of slash habitat was present south of Hazen along Oak Creek.

**De Valls Bluff.** - This quad contains the hills and bluffs along the White River and portions of the White

River floodplain (Fig. 11). Only the area west of the White River floodplain is considered part of the Grand Prairie. The topography of the quad is highly dissected and elevations range from >220' along Pfennighausen Ridge located north of De Valls Bluff to 170' at Blue Lake. The bluffs and ridges of the quad were formerly covered with upland forest. The upper end of Honey Creek is mostly >210' and likely contained some open upland-type savanna. Prairie habitat in the quad was restricted to a small area of terrace >220' west of De Valls Bluff. Bottomland forest occurred in most areas < 200' and included the White River floodplain.

**Roe.** - The Roe quad contains a mixture of interspersed habitats and topography (Fig. 12). On the east and north sides of the quad, hills adjoin the White River floodplain and contain dissected and relatively steep gradient slopes along Honey, Washington, and Branch Whiskey creeks. The lower elevations (<215') of these stream bottoms and the White River floodplain contained bottomland hardwood forest, but hills contained upland forest. Prairie terrace (>215') occurred in a fairly linear band between upland hills and the La Grue Bayou floodplain to the south and west. Prairie also was present southwest of La Grue Bayou starting in the Wingmead Prairie area. An upland-type savanna was present east of Gray Prairie and near Hurricane Church. The La Grue Bayou floodplain was covered by bottomland hardwood forest habitats and included some low scrub/shrub and cypress/tupelo habitat. Some unique cypress and tupelo brakes also occurred where Honey and Whiskey creeks joined and emptied into the White River floodplain. A very narrow slash occurred in the small drainage above Mt. Carmel Church.

**Slovak.** - The Slovak quad is higher elevation prairie

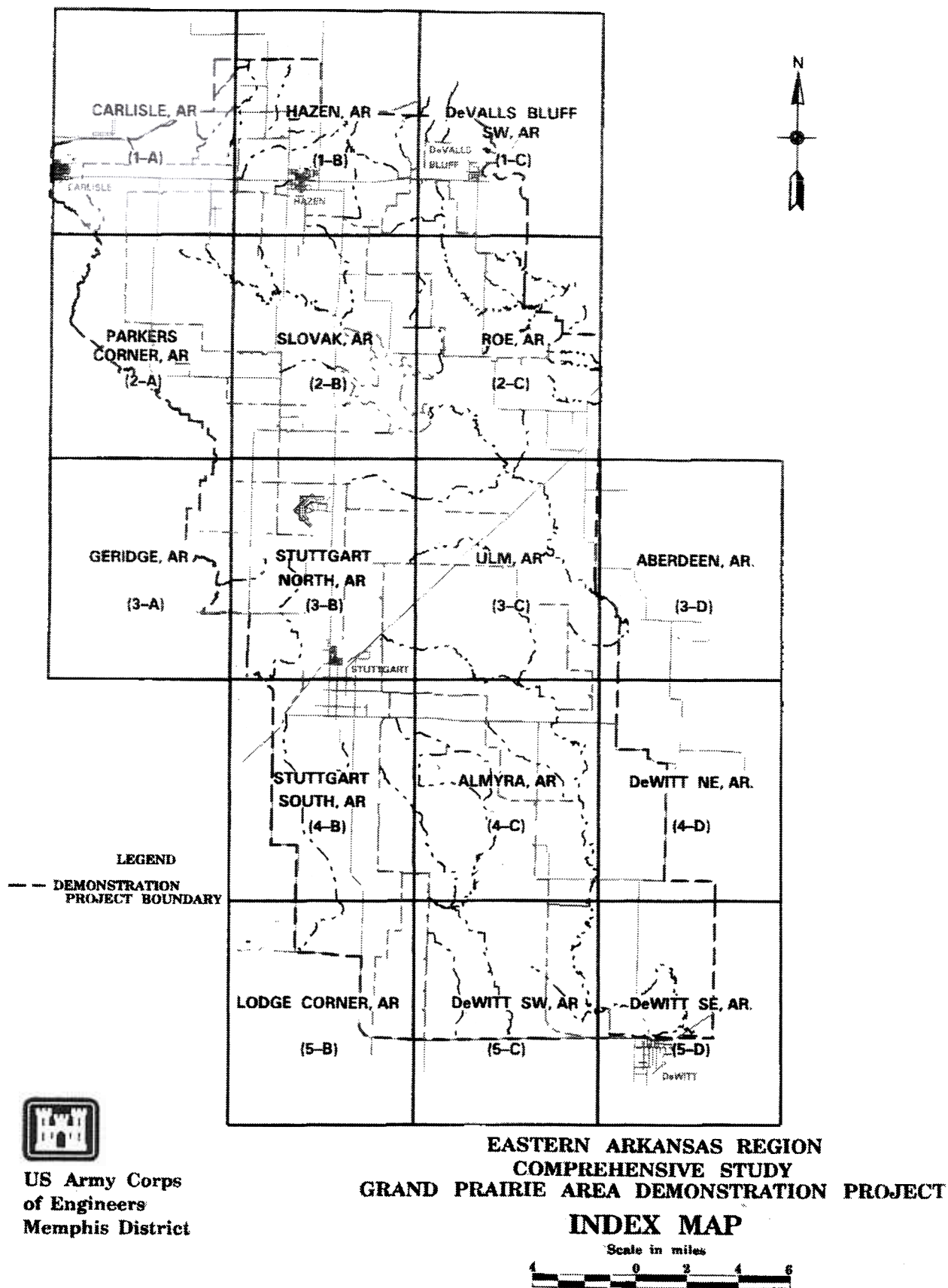
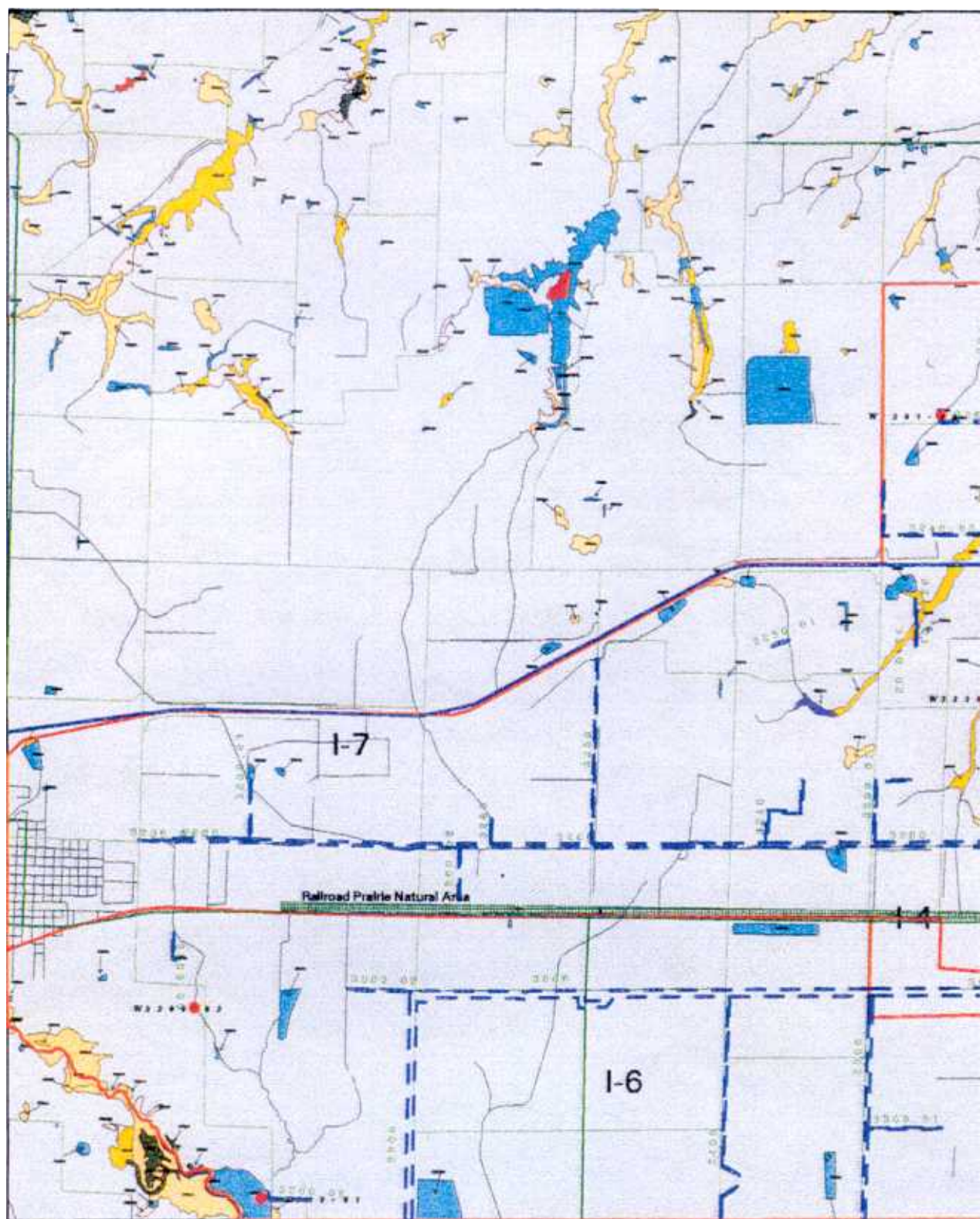
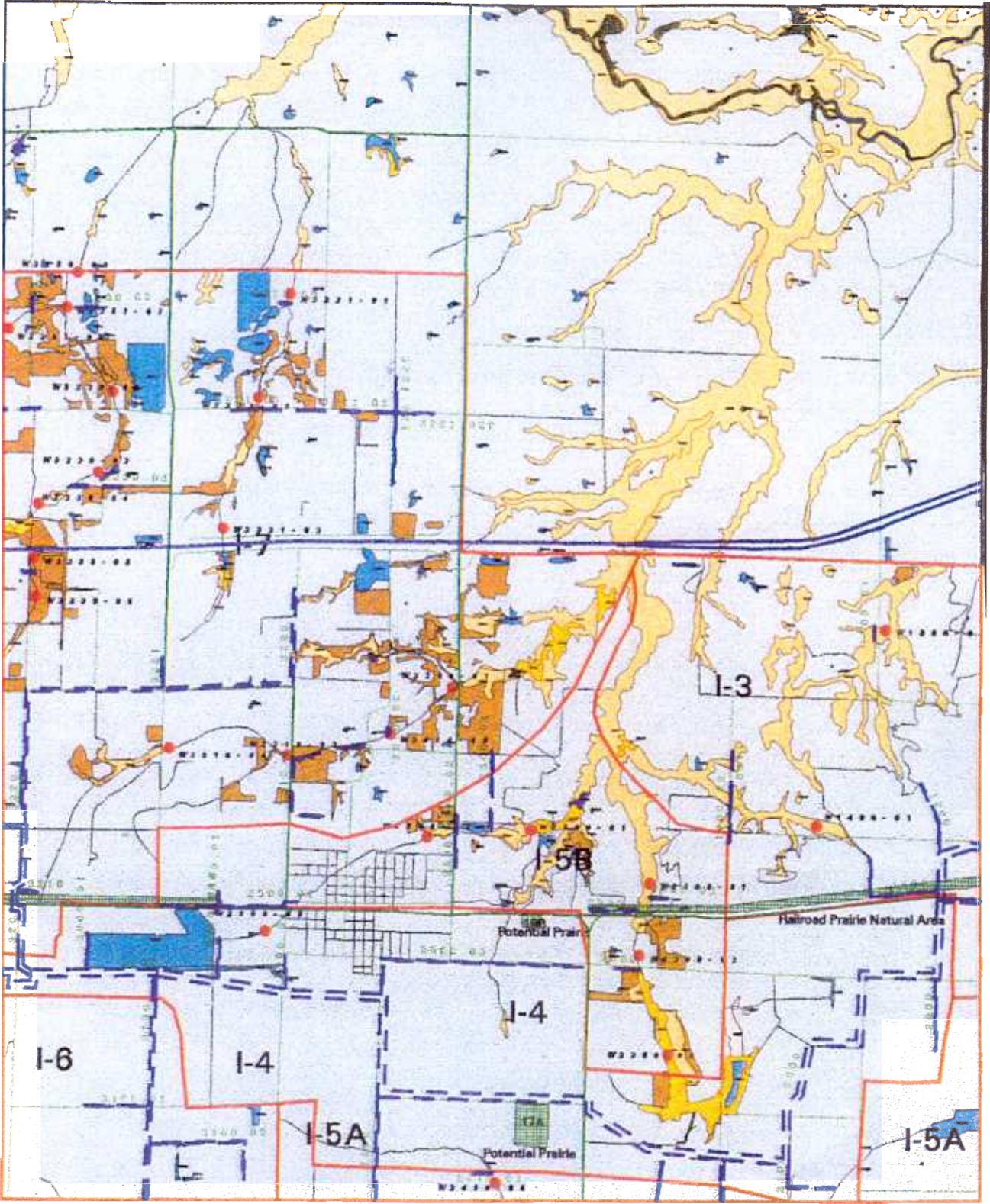
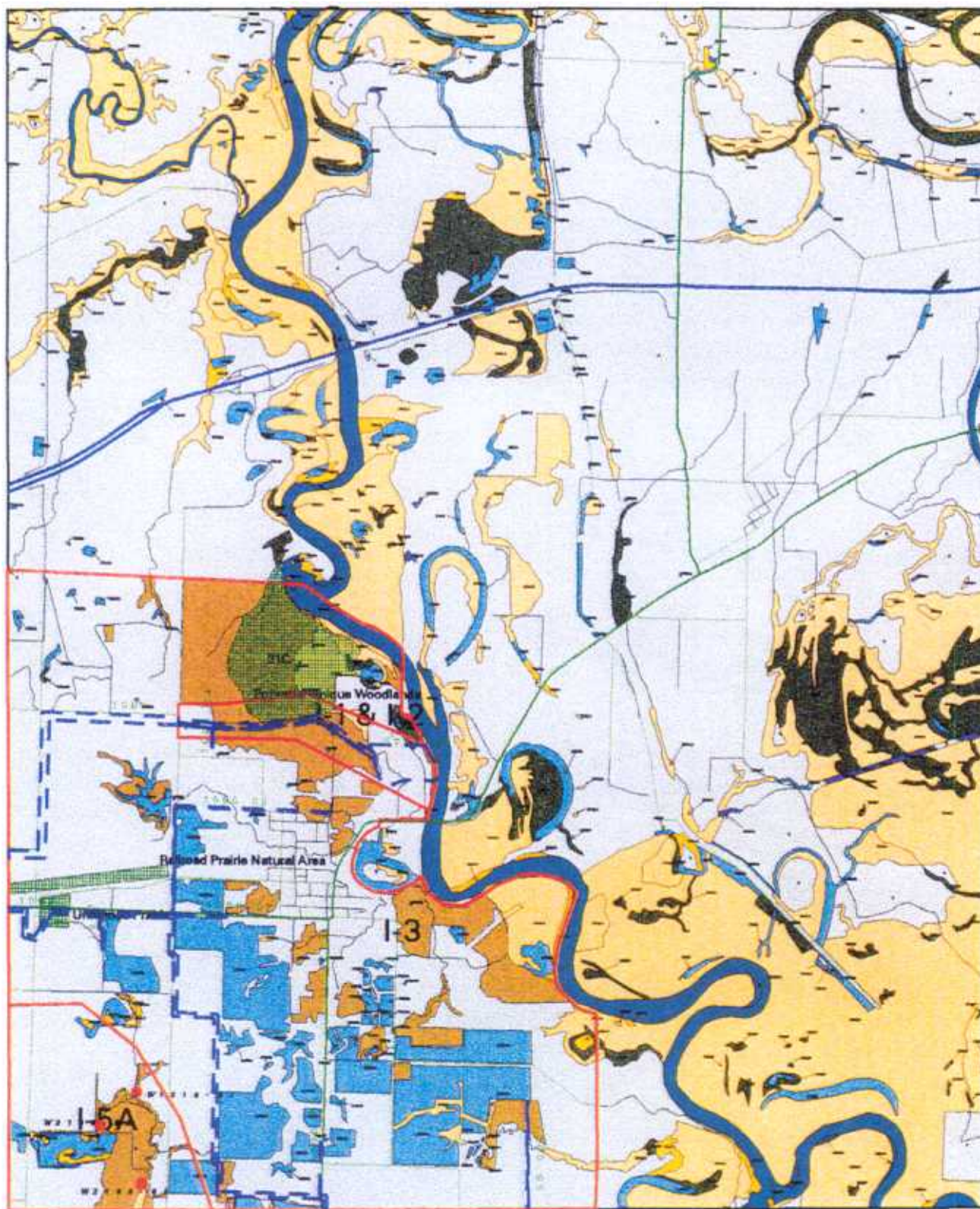


Figure 8. U.S. Geological Survey 7.5 minute quadrangles within the Grand Prairie Demonstration Project.

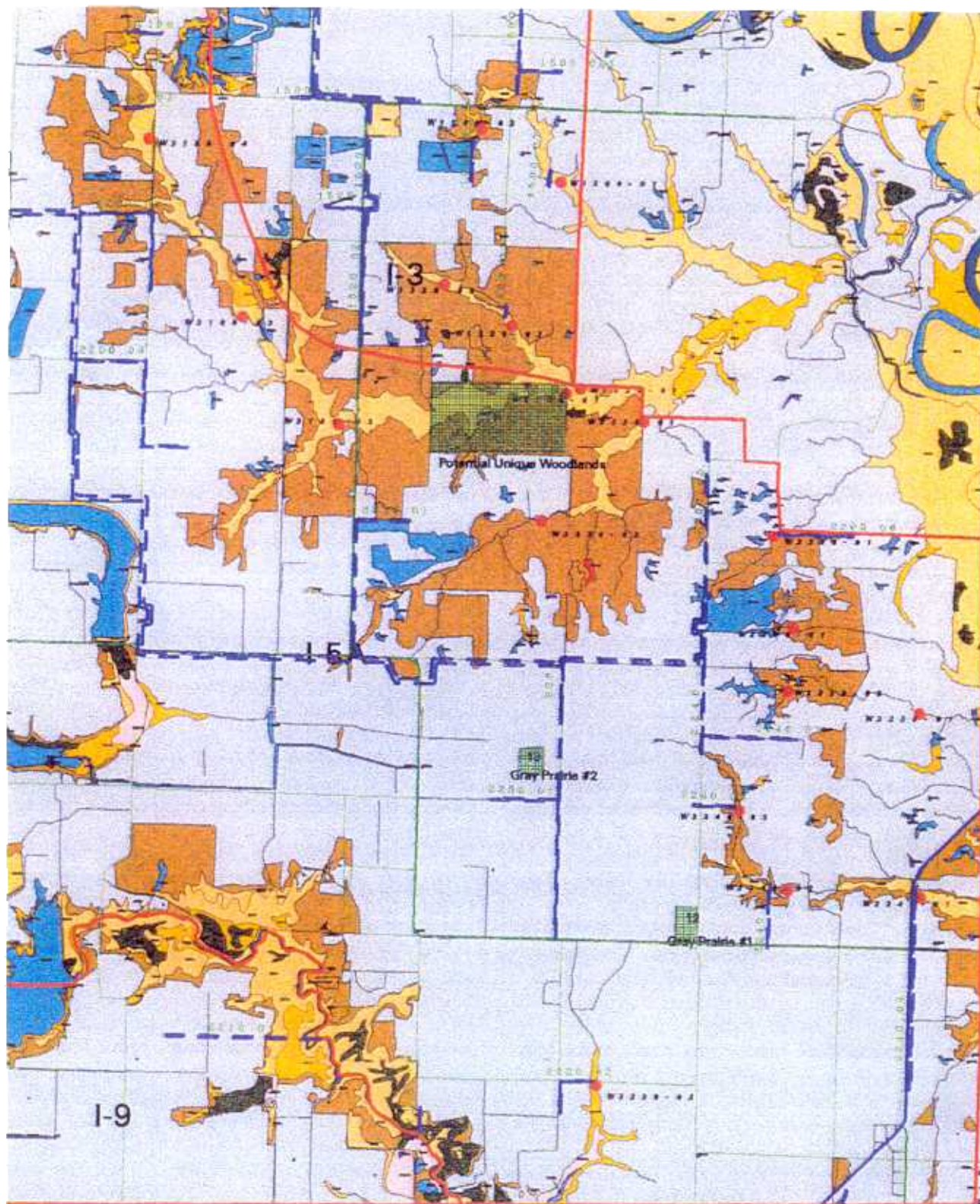


**Figure 9.** Landscape configuration and current habitat types within the Carlisle quadrangle of the Grand Prairie of Arkansas (from USACE 1999).





**Figure 11.** Landscape configuration and current habitat types within the De Valls Bluff quadrangle of the Grand Prairie of Arkansas (from USACE 1999).



**Figure 12.** Landscape configuration and current habitat types within the Roe quadrangle of the Grand Prairie of Arkansas (from USACE 1999).

rie terrace (>215') dissected by LaGrue Bayou and its tributaries Oak Creek and Wolf Island Slash (Fig. 13). A broad low flat begins at the northwest part of the quad and contained terrace hardwood forest. Elevations above 215' were prairie. Slashes existed at the upper ends of Wolf Island Slash, Oak Creek, and Lost Island Bayou. The current Konecny Grove Slash represents the remnant upper end of the former slash along Lost Island Bayou. Bottomland forest covered the entire La Grue Bayou floodplain. Bottomland forest apparently extended into the prairie terrace at 210-215' and there is some evidence for narrow bands of lowland-type savanna along the prairie-floodplain boundary.

**Parkers Corner.** - This Parkers Corner quad contains a mixture of prairie terrace, the broad floodplain of Two Prairie Bayou, and the extensive low flat south and west of South Branch of La Grue Bayou (Fig. 14). The prairie terrace south and west of Two Prairie Bayou is >210' and named "Long Prairie." Prairie east of Two Prairie Bayou is located >220' and included disjunct patches separated by bottomland and terrace hardwood forest. Bottomland forest occupied the Two Prairie Bayou floodplain, and terrace hardwoods were present in the South Branch flat. Aerial photographs indicate considerable low-type savanna adjacent to the South Branch flat grading into prairie at its edges. This savanna included the Two Prairie Bayou Wildlife Management Area. A small amount of slash habitat was present at the upper end of Wolf Island Slash and was unique because it was between the South Branch flat and La Grue floodplains both of which were covered with bottomland forest. A very small area of slash also was present near the Halijan prairie. This area probably also contained narrow strips of savanna that represented the ecotone between the Two Prairie Bayou floodplain and the Grand Prairie terrace.

**Geridge.** - Only the very northeast part of the Geridge quad is within the Grand Prairie region. This area east of Two Prairie Bayou and north of Highway 130 is mostly <205' and within the floodplain of Two Prairie Bayou (Fig. 15). Aerial photographs from the early 1900s show that all of this area was in bottomland hardwood forest. A slough that represents an old meander of the Arkansas River is located on a north-south line near Tate Cemetery and contains scrub/shrub and some bald cypress habitat.

**Stuttgart North.** - Much of the Stuttgart North quad lies on the main Grand Prairie terrace and was formerly prairie (Fig. 16). The prairie terrace northwest of Stuttgart was rolling and probably contained numerous small seasonal herbaceous wetlands. Small drainages extend into the terrace along Clearpoint Creek, Lost Island Bayou, and the head of Little La Grue Bayou. The upper ends of each of these drainages contained narrow corridors of slash habitats at

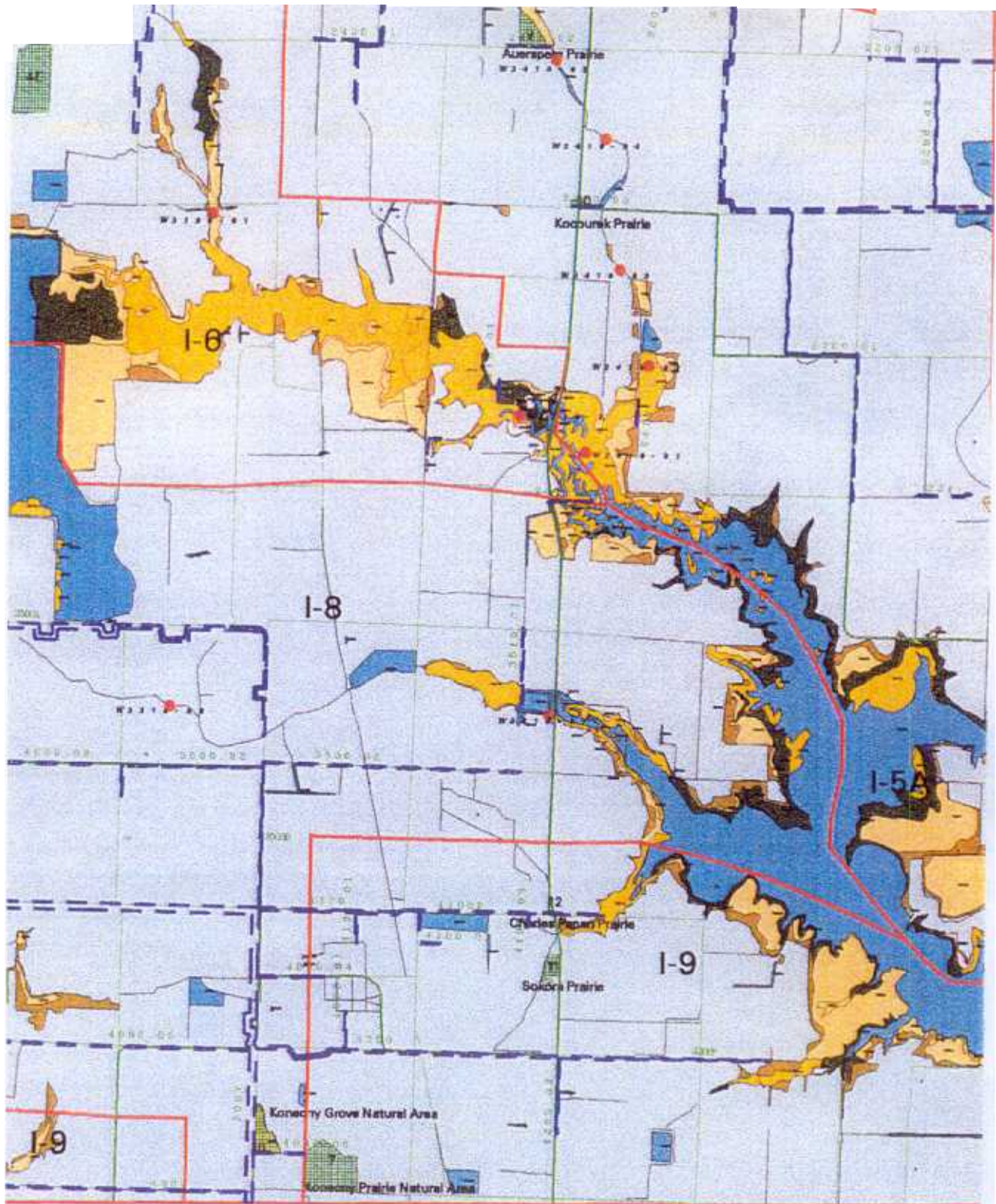
210-215'. The floodplain along Little La Grue Bayou and the lower part of Clearpoint Creek contained bottomland hardwood forest. A broad slightly depressed "flat" on the eastern side of Stuttgart contained terrace hardwood forest and was locally known as "Big Island Timber." A second large flat of terrace hardwood forest occurred in the northeastern part of the quad. These corridors and flats of forest were 200-210'.

**Ulm.** - The Ulm quad contained a very interspersed prairie-forest landscape in the early 1800s (Fig. 17). The highest elevations in the quad are 205-210' and are relatively flat and previously contained prairie grasslands. Streams that dissected the area included the larger floodplain of La Grue Bayou and its tributaries Sherrill Creek, Lost Island Bayou, Elm Slough, and Little La Grue Bayou. Floodplain corridors of each of these creeks contained bottomland hardwood forest. A depressional flat located east of Stuttgart contained terrace hardwood forest and was locally known as "Maple Island." The name implies that this forest had some upland type trees and probably was partly savanna. Some savanna also occurred near the junction of Lost Island and La Grue bayous and east of La Grue between Roe and Lookout. All of the area east of La Grue Bayou was forested and graded into upland communities along the White River bluffs and the head of Big Creek.

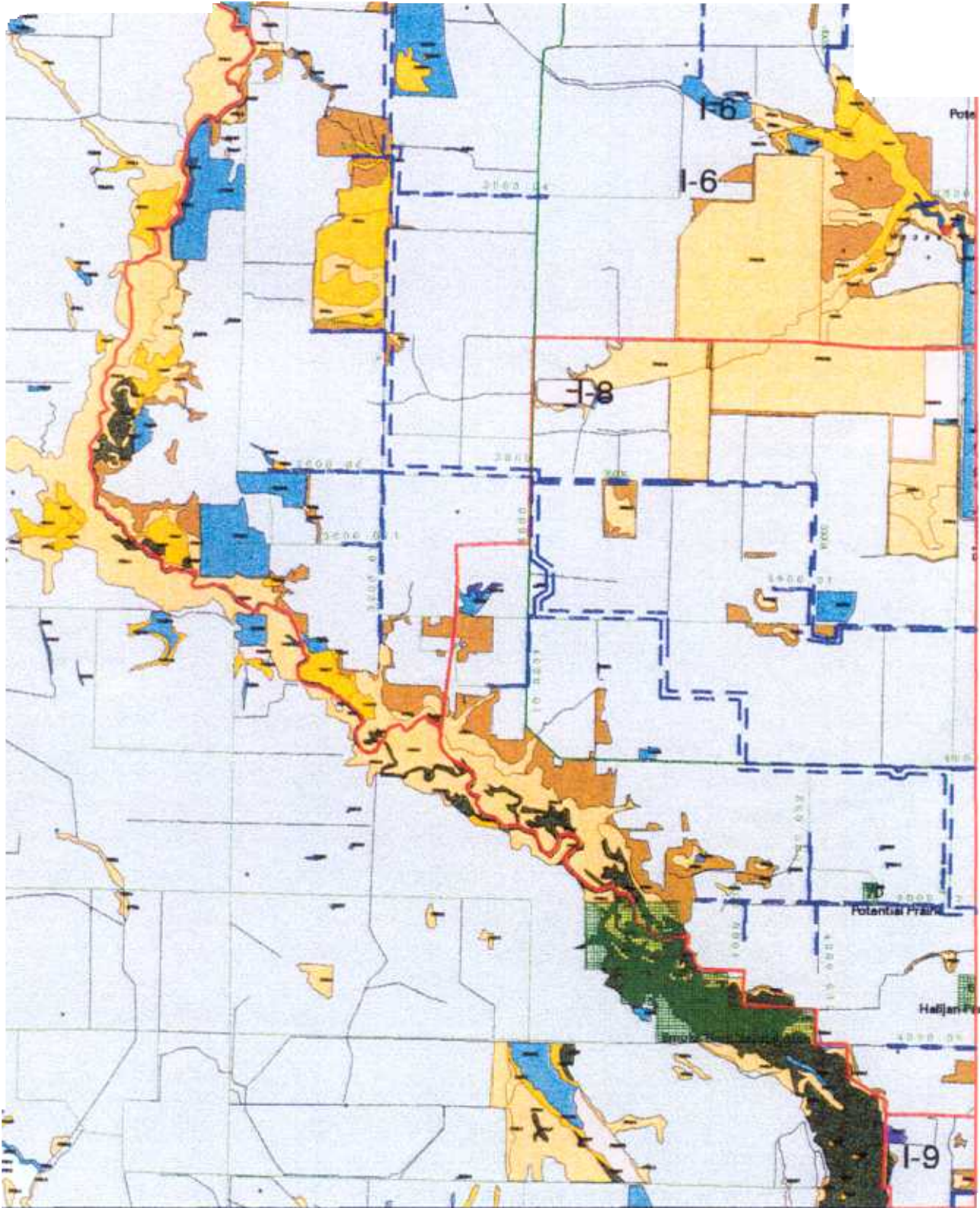
**Aberdeen.** - The Aberdeen quad is dominated by bluffs and floodplain of the White River. Apparently all of the area was forested with the possible exception of a small patch of prairie southeast of Casscoe (Fig. 18). Most of this quad was in upland and high savanna forest, except for narrow corridors of bottomland forest along the drainages <205' and the La Grue Bayou floodplain south of Mt. Calvary Church.

**De Witt NE.** - La Grue Bayou runs through the middle of this quad and its floodplain and tributaries contained bottomland hardwood forest in the early 1800s (Fig. 19). Lands east of La Grue Bayou grade into upland forest along the bluffs of the White River. Some savanna and terrace hardwood habitat likely was present on the ecotone between bottomland and upland forest along ridges and upper ends of drainages. The size and distribution of savanna in this area is not known, but probably was not extensive. Small areas of prairie may have been present at 200-205' southwest of Immanuel and southwest of Crocketts Bluff. In these locations, narrow bands of slash may have been present along Big Creek and other small drainages that extended into the prairie.

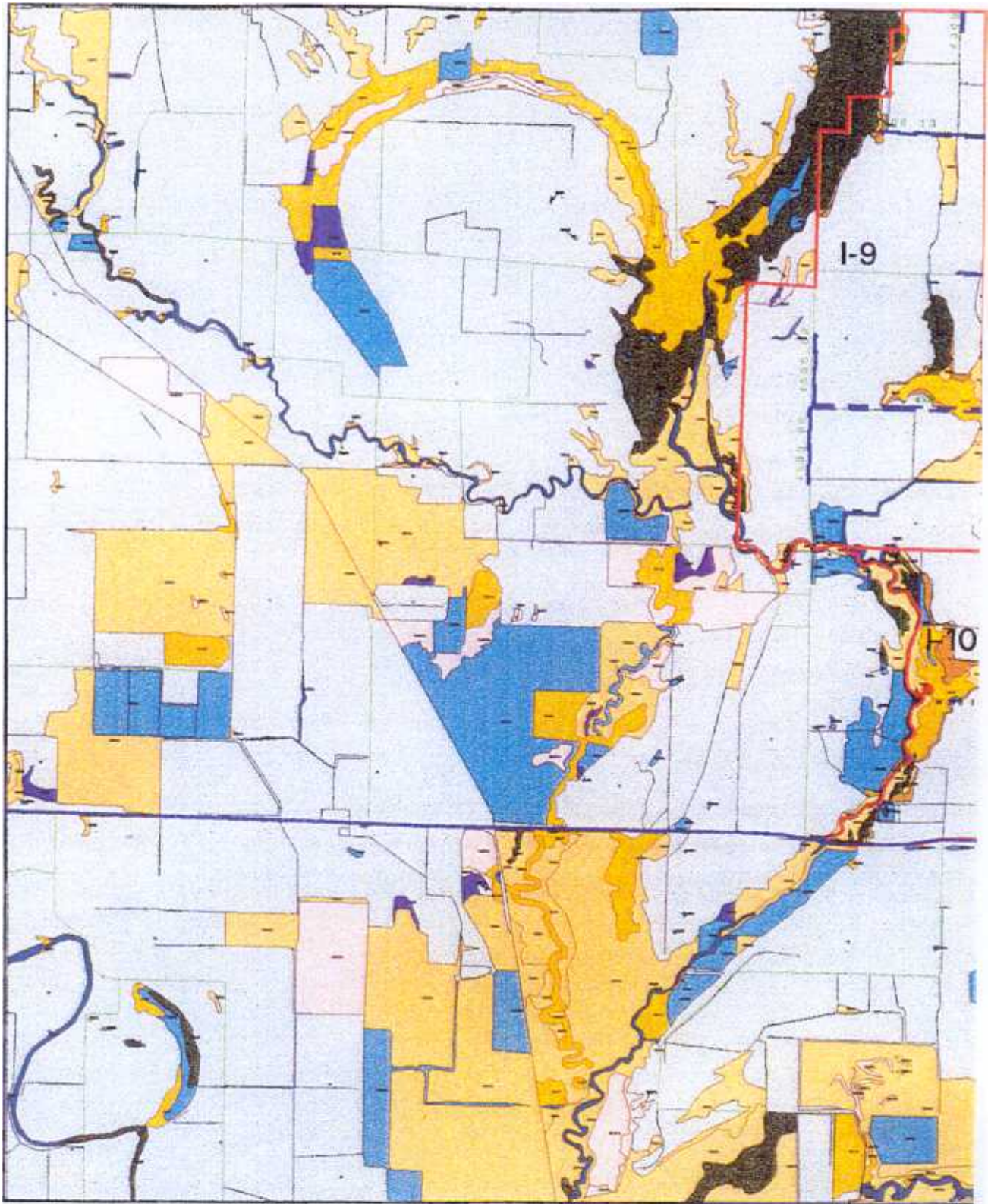
**Almyra.** - The Grand Prairie terrace extends south through the middle of the Almyra quad and was a relatively flat ridge top of 205-215' that contained continuous prairie habitat (Fig. 20). This prairie had more rolling topography northwest of Mill Bayou and may have contained a combination of prairie sloughs and



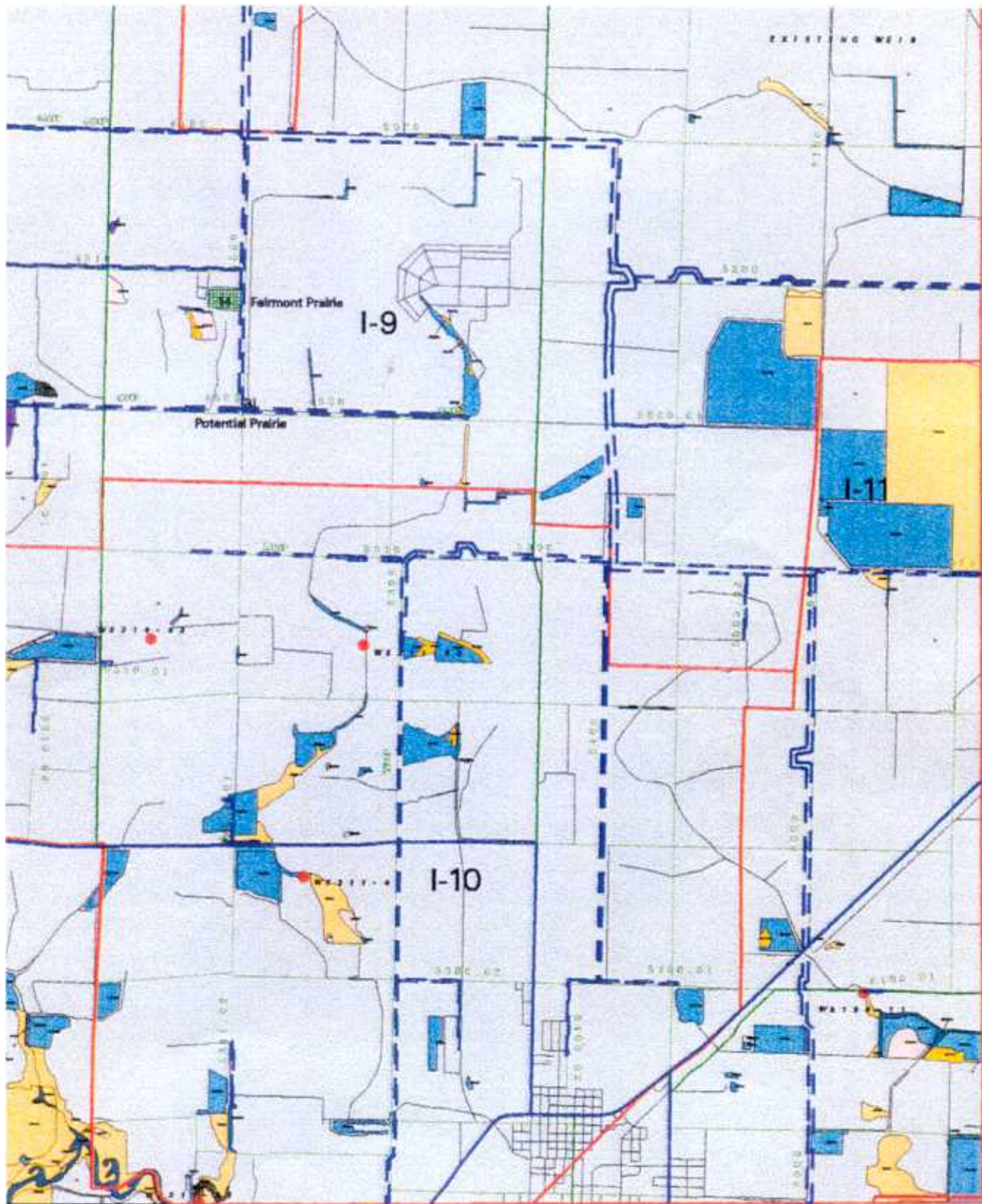
**Figure 13.** Landscape configuration and current habitat types within the Slovak quadrangle of the Grand Prairie of Arkansas (from USACE 1999).



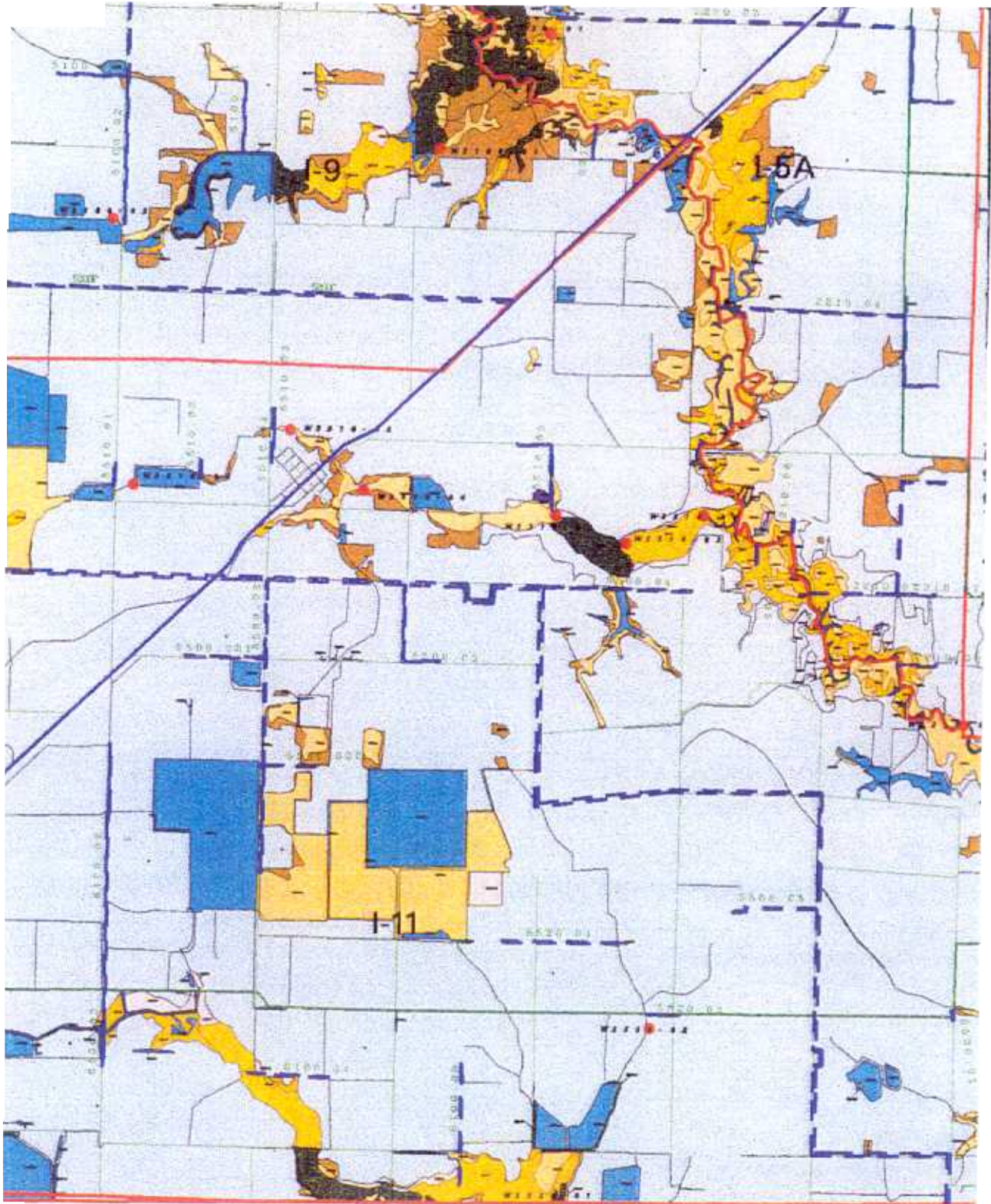
**Figure 14.** Landscape configuration and current habitat types within the Parkers Corner quadrangle of the Grand Prairie of Arkansas (from USACE 1999).



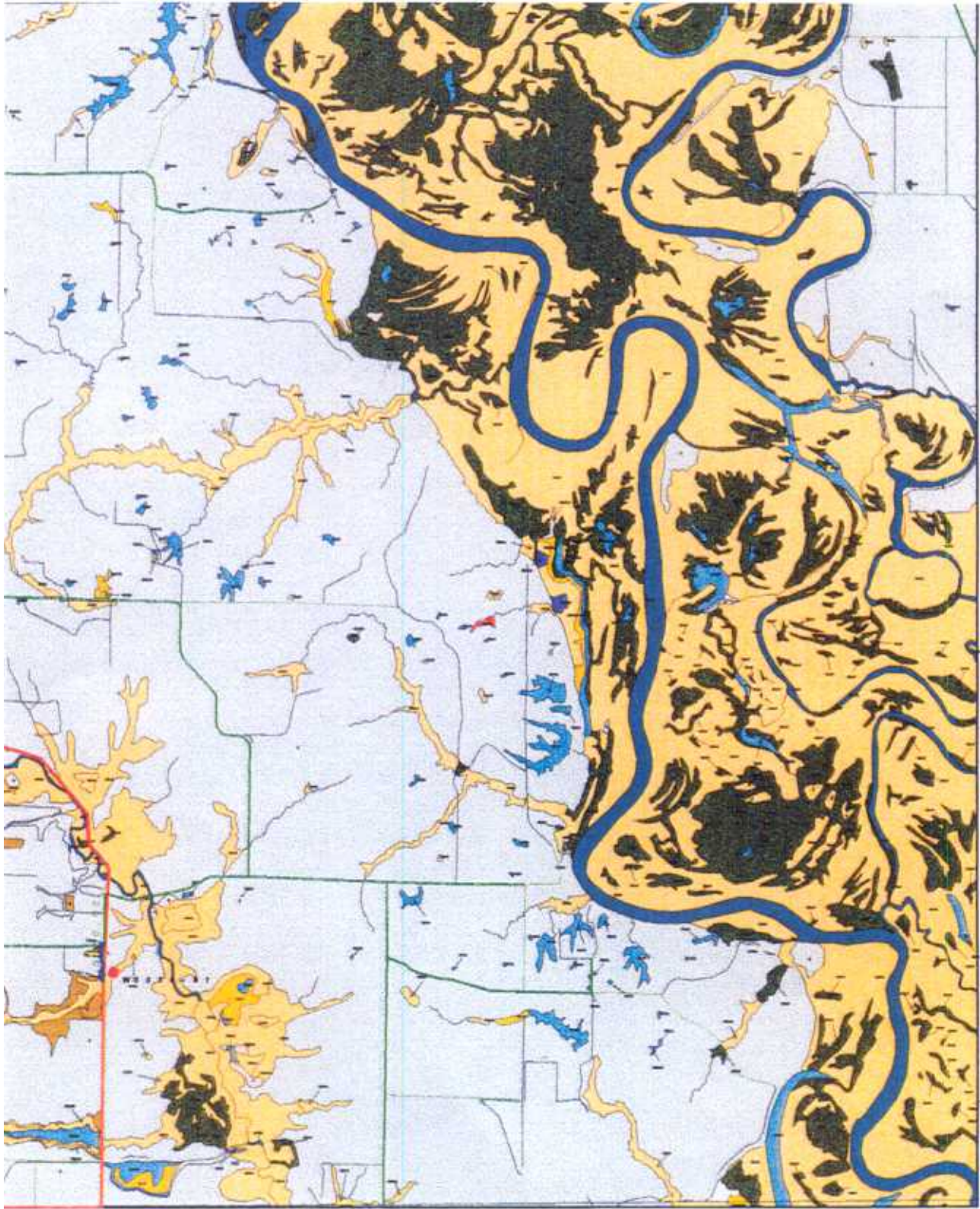
**Figure 15.** Landscape configuration and current habitat types within the Geridge quadrangle of the Grand Prairie of Arkansas (from USACE 1999).



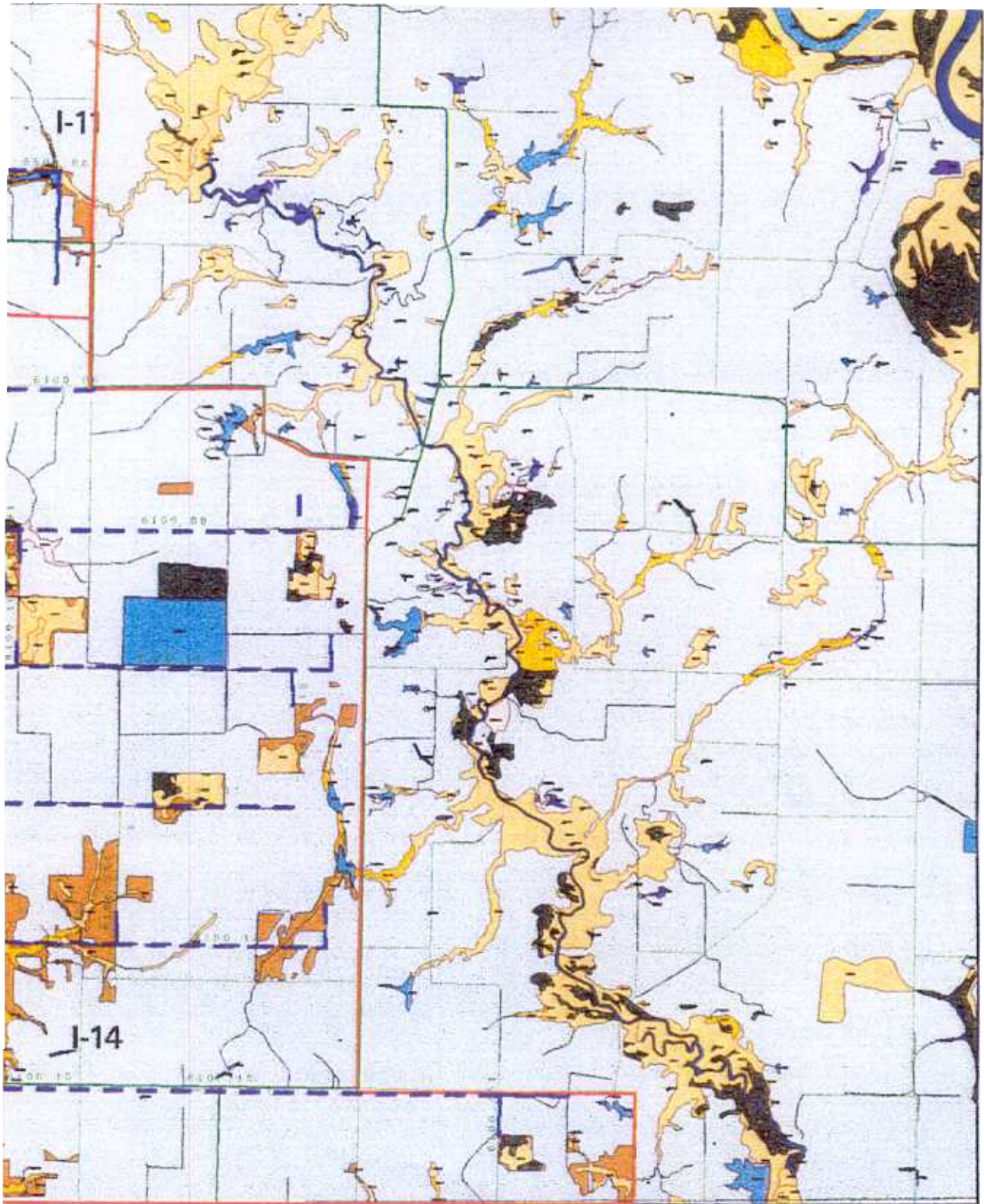
**Figure 16.** Landscape configuration and current habitat types within the Stuttgart North quadrangle of the Grand Prairie of Arkansas (from USACE 1999).



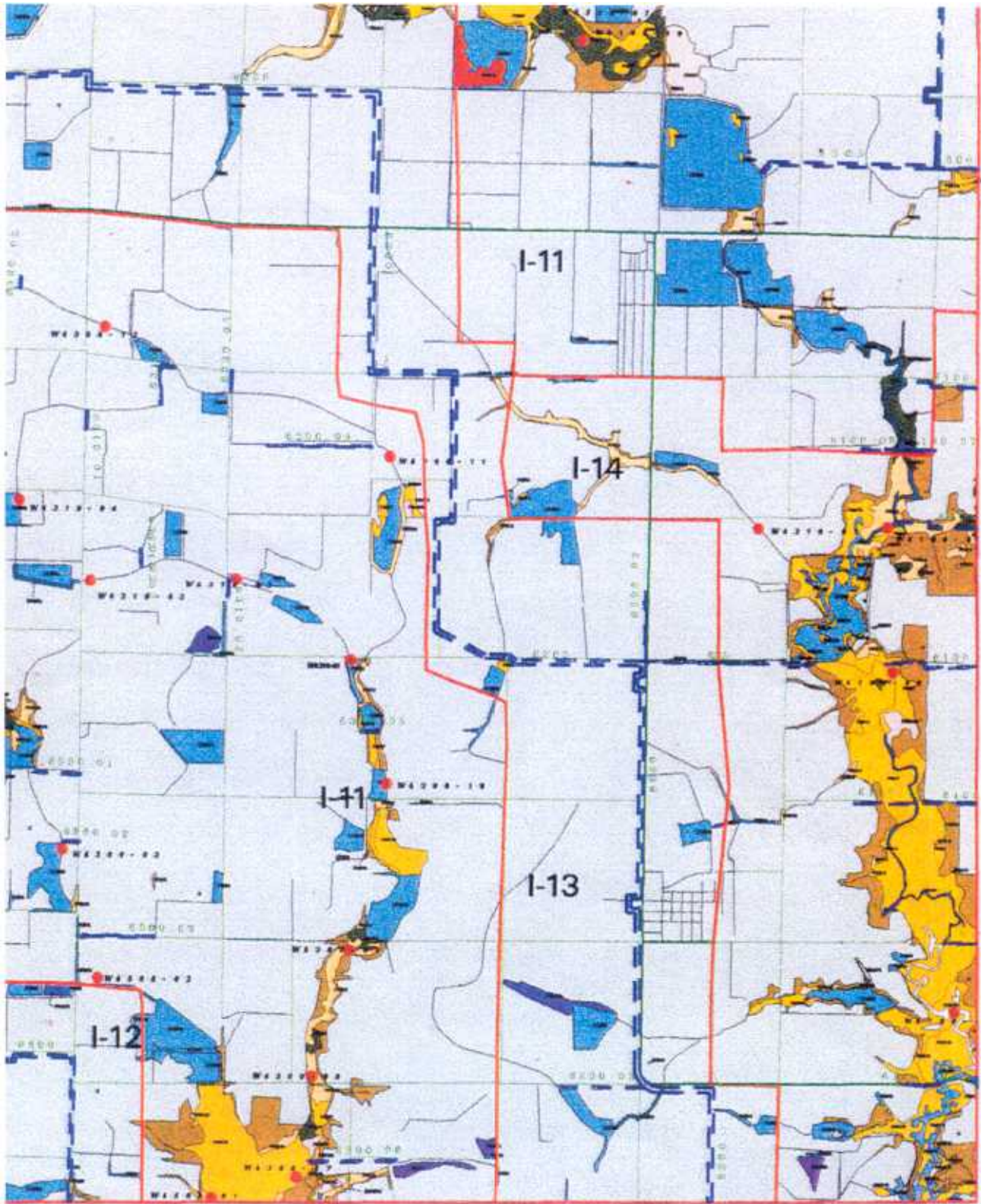
**Figure 17.** Landscape configuration and current habitat types within the Ulm quadrangle of the Grand Prairie of Arkansas (from USACE 1999).



**Figure** Landscape configuration and current habitat types within the Aberdeen quadrangle of the Grand Prairie of Arkansas (from USACE 1999).



**Figure 19.** Landscape configuration and current habitat types within the De Witt NE quadrangle of the Grand Prairie of Arkansas (from USACE 1999).



**Figure 20.** Landscape configuration and current habitat types within the Almyra quadrangle of the Grand Prairie of Arkansas (from USACE 1999).

seasonal herbaceous wetlands interspersed within grasslands. The prairie terrace was bisected by Mill and Little La Grue bayous and these floodplains contained bottomland forest. A very narrow band of savanna extended along the drainages where bottomland forest adjoined prairie at 195-200'. Slash occurred at the upper end of Mill Bayou where it began drainage of the prairie terrace through several feeder drains including Wildcat Ditch.

**Stuttgart South.** - Lands in the Stuttgart South quad primarily were prairie (200-205') with the exception of terrace hardwood forest present in the Angelica Island flat and bottomland hardwoods in the Bayou Meto floodplain along the west boundary of the Grand Prairie region and along King Bayou south of Stuttgart (Fig. 21). Slash habitat occurred along the upper end of Elm Prong Mill Bayou and extended northward from Angelica Island and along the upper end of King Bayou. The prairie southwest of Stuttgart is rolling and probably had several seasonal herbaceous wetland basins.

**Lodge Corner.** - Most of the Lodge Corner quad was bottomland forest extending from the Bayou Meto floodplain northward along King and Kaney bayous (Fig. 22). An island of terrace hardwood forest was present in the flat immediately north of Lodge Corner that drained into King Bayou. Prairie was present in the very northeast part of the quad on the ridge that traversed the terrace west of Mill Bayou. A very small amount of savanna may have been present near the prairie edge. Little to no slash was present in this area.

**De Witt SW.** - The De Witt SW quad is dissected by three main drainage systems running north to south; Hurricane, Mill, and Little La Grue bayous (Fig. 23). The floodplains (<190') of each of these bayous contained bottomland hardwood forest and the ridges (195-200') separating bayous contained prairie. Slash habitats probably extended along Hurricane Bayou into the prairie. Topographic relief along Little La Grue Bayou is marked and bottomland forest changed into upland and upland-savanna forest away from the bayou channel especially along its eastern side near Thompson Cemetery. In these areas the transition between forest types was rapid and habitat bands were narrow because of the sharp elevation gradients. Conversely, a portion of the Mill Bayou floodplain is very low (<180') and flat and contained relatively wide bands of cypress/tupelo and scrub/shrub habitats.

**De Witt SE.** - La Grue and Little La Grue bayous join in this quad and their floodplains were covered with bottomland hardwood forest (Fig. 24). Upland forest was present east of La Grue Bayou along the White River bluffs. Prairie was present south of De Witt and in an isolated patch south of Immanuel. Disjunct prairie patches also were present along Highway 1 between Crocketts Bluff and St. Charles. The sepa-

ration of all these prairie patches represent the oldest expansion of drainages and bottomland forest into the Grand Prairie from the lowest, better drained, south end of the region. By the early 1800s, it appears forest was expanding rapidly into this area and remnant patches of prairie were small and highly fragmented. Much of the center part of the quad shows evidence of gradual erosion, and gentle swales and hills form the top parts of drainages. In these areas, considerable savanna habitats were present. Some savanna bordered floodplain forests along higher elevations.

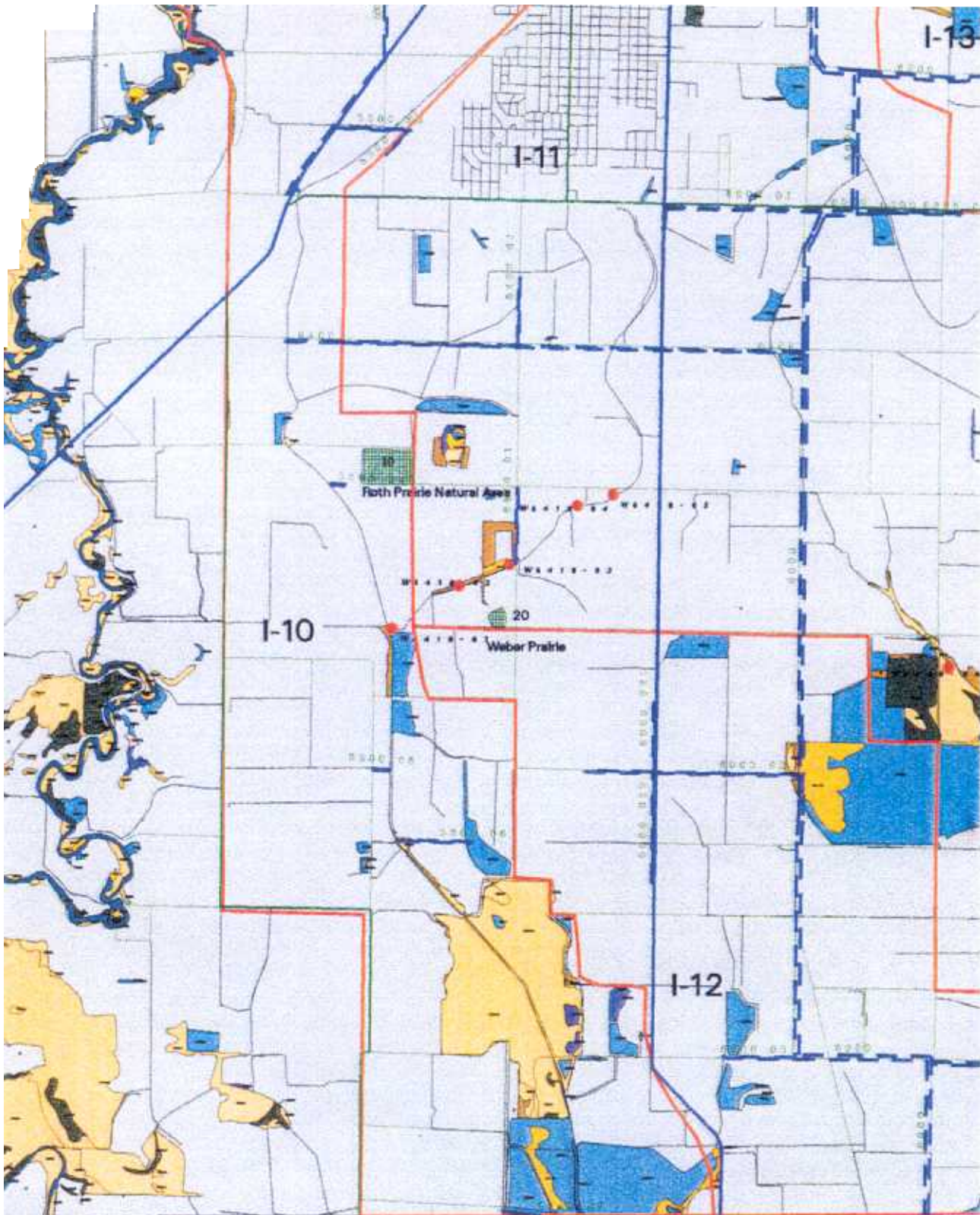
## CHANGES IN THE GRAND PRAIRIE ECOSYSTEM FROM PRESETTLEMENT TO PRESENT

### Native Vegetation Communities

The above analyses of the types, amounts, and distribution of native vegetation habitat types in the Grand Prairie region in the early to mid-1800s is the baseline for determining changes in the ecosystem from the Presettlement period to the present. As stated, future information may modify maps of the Presettlement landscape, but historical maps and accounts suggest the approximate distribution of major habitat types (prairie and forest) is fairly accurate. To compare Presettlement and current condition, we determined approximate area of habitats for the entire Grand Prairie region and for the area within the Grand Prairie Area Demonstration Project. Distribution and area of current habitats within all USGS quads that included the Demonstration Project previously were determined by the University of Memphis Ground Water Institute (USACE 1999). We used the above data and land cover maps prepared by the Arkansas Natural Heritage Commission to estimate current habitat acreage for the entire Grand Prairie region.

Total native habitats have declined 73.1% and 88.7% in the entire Grand Prairie and the Grand Prairie Area Demonstration Project area, respectively, between Presettlement and current periods (Table 8). Prairie grasslands, seasonal herbaceous wetlands, slash, and savanna habitats all declined 95% or more in both areas. Over 83% of Presettlement bottomland hardwood forests have been cleared in the Demonstration Project area and nearly 50% of this forest has been cleared in the entire region. Terrace hardwood forests have declined 75% and over 90% in the entire Grand Prairie and Demonstration Project area, respectively. About 56% of upland forests have been cleared in the Grand Prairie. The cumulative loss of native vegetation in the Grand Prairie is among the highest loss for any ecosystem region in North America.

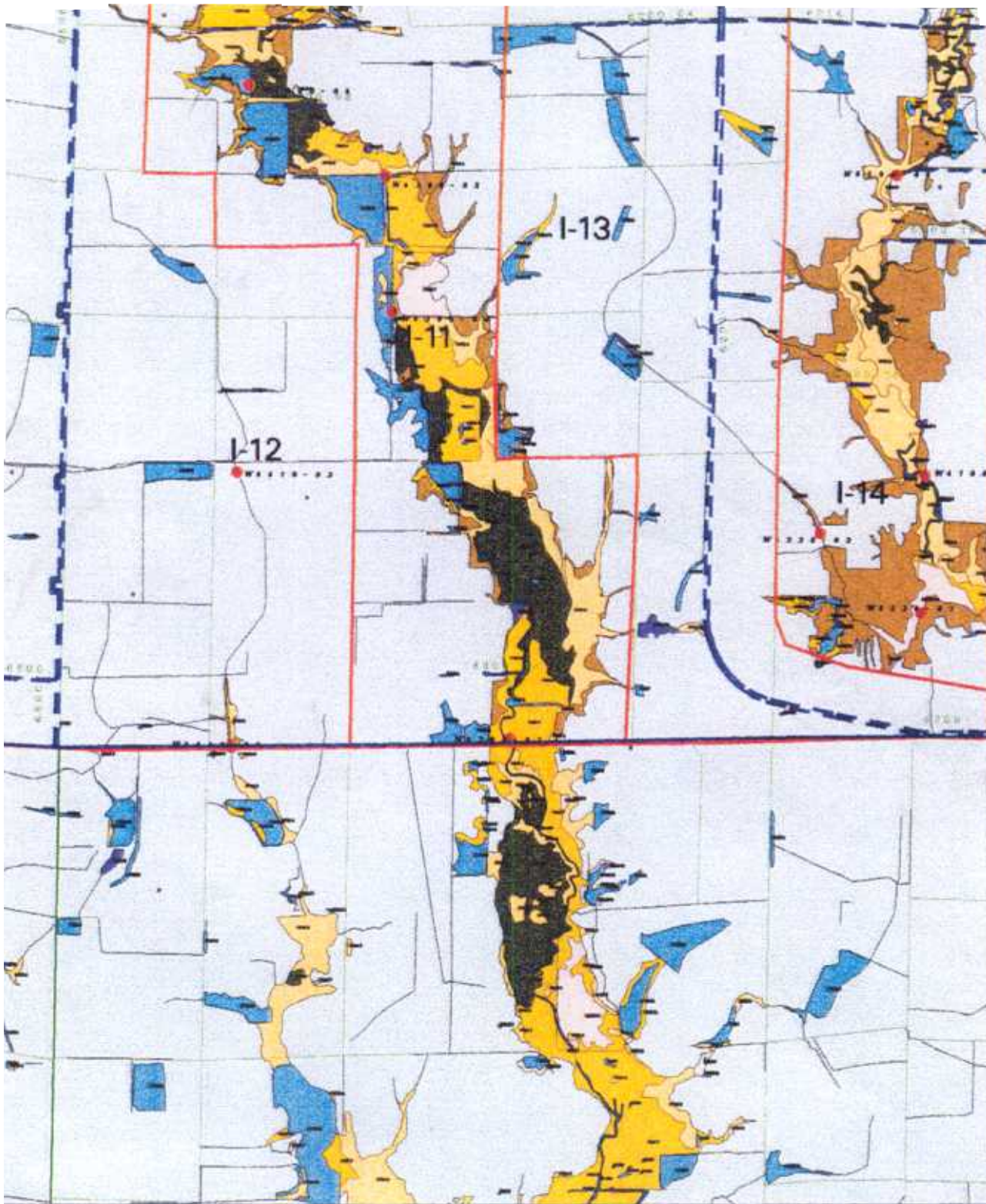
Most of the native vegetation in the Grand Prairie region has been replaced with agricultural cropland. Within the Demonstration Project (where current land



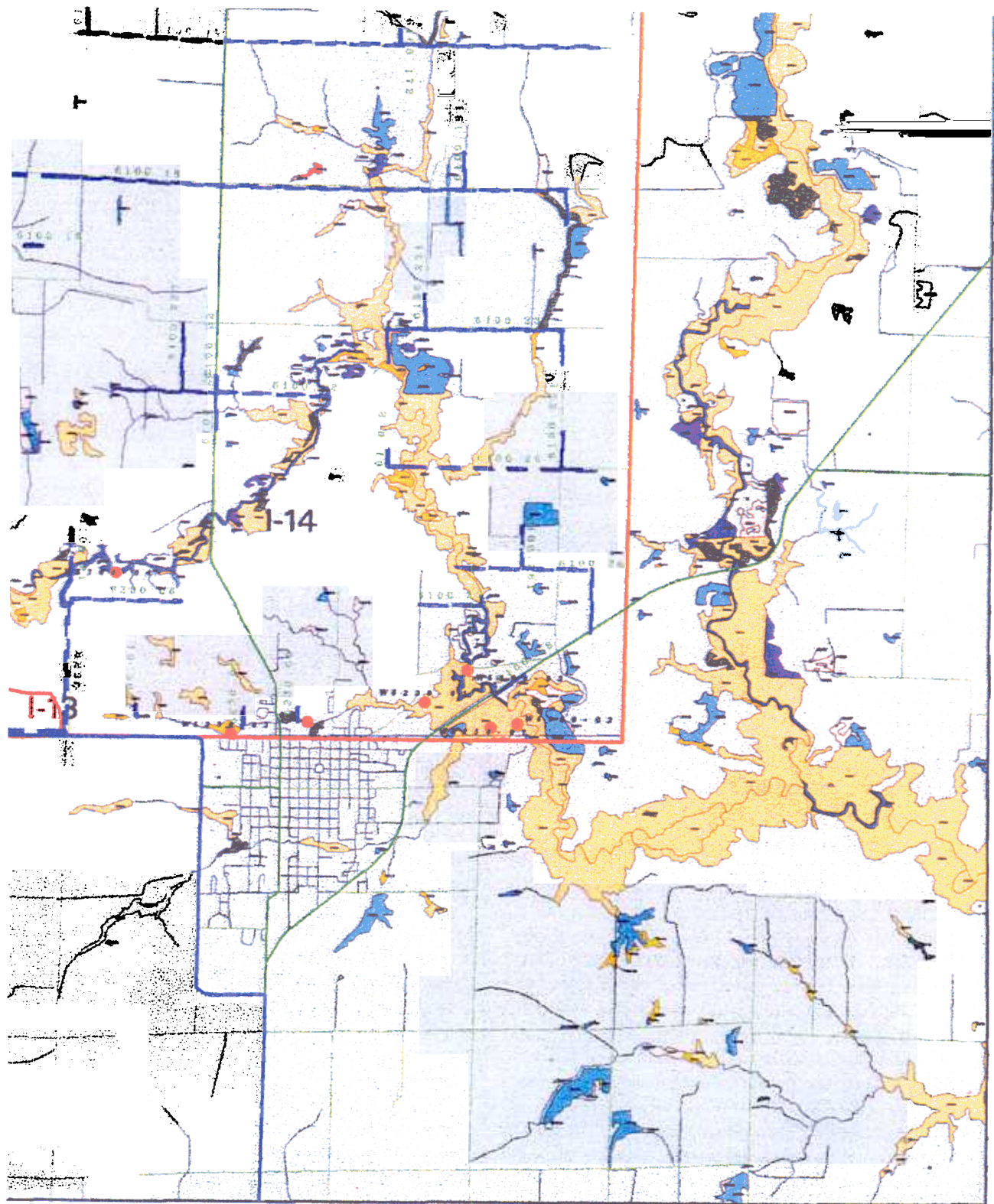
**Figure 21.** Landscape configuration and current habitat types within the Stuttgart South quadrangle of the Grand Prairie of Arkansas (from USACE 1999).



**Figure 22.** Landscape configuration and current habitat types within the Lodge Corner quadrangle of the Grand Prairie of Arkansas (from USACE 1999).



**Figure 23.** Landscape configuration and current habitat types within the De Witt SW quadrangle of the Grand Prairie of Arkansas (from USACE 1999).



**Figure 24.** Landscape configuration and current habitat types within the De Witt SE quadrangle of the Grand Prairie of Arkansas (from USACE 1999).

use data are most accurate), approximately 255,000 (70%) of the total 363,000 acres is now cropland. Over 97% of this cropland is irrigated, mostly in a rice-soybean crop rotation. About 2,300 acres of cropland have been enrolled in the USDA Conservation Reserve Program (CRP) since 1985; most of this land has been planted to non-native loblolly pine. Other current land uses that do not include native vegetation include 15,556 acres of irrigation reservoirs and 50,377 acres of miscellaneous roads, ditches, urban areas, homesteads, and levees.

Most of the loss of native vegetation in the Grand Prairie region occurred in the early 1900s (Corbet 1966). Up until 1900, the number of settlers on the prairie terrace was limited, and most prairie lands were not tilled because the claypan made tillage difficult and crop production poor. Farmers used prairie land for haying and grazing livestock. Most settlements in the Grand Prairie region in the late 1800s were confined to the edges of forests, near larger rivers, and often near the "islands" of terrace hardwood forest. Small patches of forest were cleared and farmed near towns, but the total area of cleared agricultural land was relatively small.

The first successful rice crop in the Grand Prairie was grown in 1904 near Lonoke (Spicer 1964). After rice production started on the prairie terrace, more farmers moved to this area and extensive clearing and tilling of prairie grasslands and small seasonal wetlands occurred from 1905 to 1920. By 1915 over 100,000 acres of rice were planted and by 1930 almost all of the Presettlement prairie had been converted to rice lands. Aerial photographs suggest that over 60% of bottomland and terrace hardwood forests lost between Presettlement and present periods had occurred by 1940. The remaining loss of these forests occurred when reservoirs were constructed in bottomland drainages and flats during the 1940s-60s and when higher market prices for soybeans accelerated clearing of forests in the 1950s-70s. Savanna habitats were more easily converted to cropland than dense forests and most savanna was gone by the early 1900s. Slash habitats were never as abundant as other Grand Prairie habitats and were in drainage locations not suited for rice production. Declines in slash habitats may have occurred later in the century when many drainages were dammed for reservoirs, stream channels were modified for irrigation water sources, and extensive ditches and canals were constructed to move well and reservoir water to rice fields.

Remnant bottomland forests in the Grand Prairie are confined to narrow corridors along primary drainages through the region and fragmented terrace hardwoods occur in scattered isolated flats, usually on duck clubs where the forest is managed as greentree reservoirs (Figs. 9-24). Upland forest is present along the hills

and bluffs of the north and east sides of the Grand Prairie and is the least disrupted habitat compared to Presettlement times. Almost all remaining forests (all types) have been cut and logged at least once since the late 1800s. Remnant slash, savanna, seasonal herbaceous wetlands, and prairie grasslands are scattered throughout the region in tiny isolated patches. All of the remnant slash and savanna have been cut over and even today are used for firewood, pruned and mowed around towns and residences, or periodically burned and sprayed.

## Hydrology

Before European settlement, hydrology of the Grand Prairie ecosystem was driven by on-site rainfall and slow overland sheetflow into depressions on the prairie terrace and into low gradient streams. Following the advent of rice production, hydrological patterns in the region changed dramatically. Rice production required a plentiful and predictable seasonal water supply, relatively flat fields, water control structures to hold water for 2-3 months in summer, and substantial machinery and labor. Where this combination of factors occurred, rice produced abundant crops and good financial return (Spicer 1964). These agricultural activities also changed the Grand Prairie landscape forever.

## Wells

Most rainfall in the Grand Prairie area occurs from late winter through spring; summers are hot and dry with high evapotranspiration. Seasonal rainfall was not predictable nor of the right timing for consistent rice production, and consequently farmers began drilling wells to provide water to fields. Rice production in the Grand Prairie region expanded immediately after the first crop was grown in 1904 and essentially exploded around 1907 when new well drilling technology was developed and brought to the area by the Layne and Bowler Company (Spicer 1964). By 1920, an average of 100,000-125,000 acres of rice were grown annually in the prairie region and several hundred wells had been installed. All of these wells were relatively shallow (80-100' below the surface) and tapped into the Quaternary alluvial aquifer. By 1916, more water was being withdrawn from this aquifer than was being recharged annually. By 1930, many wells were declining at a rate of about a foot a year and some had gone dry. Despite evidence of a declining aquifer, pumping groundwater from wells has continued and a "cone-of-depression" of the aquifer now is present; the center being slightly north of Stuttgart. In places, the aquifer has declined nearly 80' between 1905 and 2000. In the last 20 years, total water use, particularly groundwater use, throughout eastern Arkansas has increased

dramatically and is nearly 6 billion gallons/day; about 4 billion of this is pumped groundwater (USACE 1999).

As the alluvial aquifer continued to decline in the mid-1900s, some farmers began sinking "deep" wells 450-1,100' below the surface into the Sparta aquifer of the Tertiary layer. Today about 80 of these deep wells exist. The Sparta aquifer is much more limited than the alluvial aquifer and despite less water extraction from it, the Sparta has declined as much as 100'.

As early as 1936, water quality of groundwater obtained from the alluvial aquifer began declining, and alkalinity of soils in rice fields increased (Corbet 1966). Water from the alluvial aquifer has small amounts of calcium and magnesium carbonates and when water is held on lands for long periods, calcium and magnesium salts are precipitated from the water. Consequently, after 8-10 consecutive seasons of rice production, soil pH may rise from a virgin level of 5.0-6.0 to about 7.5. The poor internal drainage of prairie soils makes it impossible to lower this pH by flushing. In 1925 soybeans were introduced to the region to rebuild soil nutrients, reduce alkalinity, and set back noxious weeds (Spicer 1964).

Most wells were drilled immediately adjacent to rice fields that were to be flooded. However, as rice expanded and soybeans were introduced as a rotation crop with rice, the need to move water farther occurred. Subsequently, small ditches were dug throughout the prairie terrace to move water from wells to fields. Ditching also occurred when additional roads were built throughout the area. In total, more than 600 wells and several hundred miles of conveyance ditches associated with wells have significantly changed the amount and quality of surface water present on the Grand Prairie. Under natural conditions, about 50 inches of rainwater was input to the region annually. Now, nearly a billion gallons of groundwater are pumped to the surface in addition to rainwater each year.

### Reservoirs and Irrigation from Streams

The early and continued deterioration of groundwater sources and water quality caused farmers in the Grand Prairie to begin to use surface water for irrigation (Corbet 1966). As early as 1908, a dam was built on Bayou Meto and a pumping station moved water over several hundred acres south of Stuttgart. Also, in 1908, a pumping plant was built on Stinking Bay adjacent to the White River and moved water onto eastern Arkansas County. Later, in 1910 a 12,000 gallons/minute relift pump was installed on the White River at Crocketts Bluff. A 6-8 mile canal carried this water and eventually watered about 1,500 acres of rice. Other farmers attempted to dam and pump water from the larger streams of the area including Bayou La Grue,

Mill Bayou, Two Prairie Bayou, and Bayou Meto. The largest of these early stream dams was built on Bayou La Grue near Almyra in 1927. However, by 1950 the number of pumps on streams, the diversion and capture of surface water runoff by reservoirs (see below), ditches, and levees had greatly reduced flows into streams and most became intermittent or dry during summer. Currently, the largest in-stream dam is on La Grue Bayou and forms the 2,400 acre Peckerwood Lake.

While some areas close to streams could use stream water for irrigation, most of the Grand Prairie terrace did not have access to stream water. Consequently, farmers began constructing on-farm reservoirs to capture and hold surface runoff. Apparently, the first such storage reservoir was built by A.A. Tindall in 1926 in a low, forested drainage south of Stuttgart (Desmarais and Irving 1983). The Tindall reservoir not only provided a dependable source of water for rice production, but the flooded forest also attracted large numbers of wintering waterfowl, especially mallards. This double benefit caused many Grand Prairie farmers and hunters to build many reservoirs in forested drainages in subsequent years. About 50 greentree reservoirs were constructed primarily for duck hunting between 1926 and 1950 (Bowman and Wright 1998). Most "greentree" reservoirs initially were managed to hold water from fall through winter and were dry during summer. Increased demands for water ultimately caused management of many of these original greentree reservoirs to change from duck hunting to irrigation storage structures. This change gradually killed the trees in reservoirs.

Water from reservoirs is lower in alkalinity than groundwater and the combination of predictability and good water quality accelerated reservoir construction primarily for irrigation purposes around 1950 (Corbet 1966). Most of the about 200 reservoirs built prior to 1950 were located in lower elevation forested sites along streams and in depressions where water could be captured. Many of these reservoirs were >100 acres. Gradually, fewer suitable forested sites were available for construction of reservoirs and more reservoirs were built on higher sites; some previously had been in cropland. Construction of these "cropland" reservoirs accelerated from the mid-1950s to about 1970 when reduced surface runoff made streams unreliable, and groundwater became depleted or very expensive to obtain (through deep wells into the Sparta aquifer). Most cropland reservoirs were small (<50 acres).

Up until 1962, all of the reservoirs in the Grand Prairie region were constructed with above ground levees and dams. Recently, a few underground reservoirs have been constructed by excavating dirt from an area. The first of these underground reservoirs was built in 1962 (Corbet 1966). Underground reservoirs fill primarily

from local runoff but are restricted to shallow excavations and sites that do not have sandy soils that cause water to be lost from downward percolation.

The need to collect and conserve surface water led farmers in the Grand Prairie region to develop surface water collection and distribution systems on their farms as early as the 1940s (Corbet 1966). A common "return system reservoir" used a series of ditches, pumpback stations, and flume ditches to not only capture all of the natural rainfall and runoff on their farms, but also to recapture and reuse water used in irrigation. This system of ditches and pumps often is elaborate and essentially eliminates overland sheetflow and runoff. In addition to above ground ditches, underground pipelines buried 30-36 inches deep commonly are employed to avoid evaporation losses and move water efficiently to desired fields. Several thousand miles of pipeline currently are in the Grand Prairie.

Currently, 15,566 acres of reservoirs exist in the Grand Prairie Area Demonstration Project area. This area of reservoirs and the associated thousands of miles of ditches, canals, pipelines, and pumpback stations have greatly altered the physical nature of the Grand Prairie and eliminated most overland sheetflow and runoff into local streams. Most streams now are intermittent and flows are mostly restricted to late winter and early spring. Overbank flooding of streams now is uncommon.

## Topography

### Roads and Ditches

Up until 1905, few people lived in the Grand Prairie region (Desmarais and Irving 1983). Most settlements were near the major rivers that bounded the region and in a few small towns located on the edge of the prairie. Settlers that lived on the prairie terrace were scattered. Few roads existed in the Grand Prairie region and only a few crude ditches were present. After rice production accelerated in the area, a "rice boom" occurred and the population of the region expanded 5 times within a few years. Real estate entrepreneurs actively marketed the region's rice culture and the rice industry itself solicited labor. By 1920, most of the prairie terrace was occupied and an extensive network of roads was built. By 1925, almost all of the prairie terrace region had a gridwork of roads along each section line, and many sections were further dissected by roads along quarter sections and to dwellings and wells. In addition to prairie roads, many roads and bridges were built across drainages. Many section roads were constructed by grading an elevated hard surface from two parallel drainage ditches on each side of the road. This construction created small levees and ditches throughout the region. Roads and road ditches diverted overland sheetflow and runoff, and each section became

its own watershed isolated from other sections unless roads and ditches were absent. This section-watershed landscape was further modified in the mid-1900s when reservoirs and associated return systems were constructed.

### Railroads

As with most developing landscapes in North America in the early 1900s, railroads were built into the Grand Prairie region to serve a growing population and the emerging rice-based economy. The first rice mill in the region was built in Stuttgart in 1907, and subsequent mills were built in De Witt in 1908, and Carlisle and Lonoke in 1909. Railroads soon connected all of the major towns and mills of the region and further altered the flat prairie terrace. Where railroads were built, a large elevated levee was constructed to support the railbed and track. Material for this levee was excavated from adjacent areas and usually created a ditch parallel to the rail levee. While not as extensive as the mile-square road gridwork, railroads and their rights-of-way, including ditches, became bisecting corridors through the prairie and forests. Where railroads crossed drainages, railbeds extended into the floodplain and blocked and diverted stream flows.

### Levees

Levees were constructed to control water in rice fields almost immediately following initiation of rice production in the Grand Prairie (Spicer 1964). Early levees were crude and mostly temporary, but improved technology and equipment quickly led to bigger and often permanent levees surrounding fields. While much of the Grand Prairie terrace was relatively flat, rice production required uniform, shallow water depths <12-18". Consequently, even small changes in elevation within fields required internal levees raised along elevation contours to maintain similar water depths within each part of the field. In many fields, several miles of internal rice levees are present within even a quarter-section of land. Currently, about 250,000 acres of cropland within the Grand Prairie Demonstration Project are annually irrigated and almost all have at least some levees present. These levees further divert surface water flow and have essentially eliminated overland sheetflow in the area. While roads and railroads created a section-watershed landscape in the prairie terrace, rice field levees further dissected the watershed into individual field and subfield units.

### Land Leveling

The need to create shallow and relatively uniform water depths in rice fields caused rice farmers not only to build contour levees in fields, but also to try to flatten or "level" fields as much as possible. The first land

leveling of Grand Prairie fields began in a tentative way in the late 1920s. The first levelers or "floats" as they were called, were crude 2 x 8" wood frames with 2 x 6" cross pieces for leveling blades. Soon thereafter, these floats became more sophisticated and steel levelers with alternating diagonal blades created a machine that moved soil both laterally and forward. Modern land planes evolved from these early levelers and today almost every agricultural field in the Grand Prairie is "planed" and leveled to some degree every year.

In addition to moving dirt within fields with floats and land planes, some farmers began more extensive land leveling as early as the 1940s. At this time, dirt excavators, road graders, and bulldozers were employed to remove high spots in fields and to fill depressions. Much of this earth moving was associated with construction of above ground reservoirs which required significant amounts of dirt for the outer levees. Some additional excavations occurred when roads, railroad beds, and floodplain crossings were built.

In the 1980s, laser technology was introduced to agriculture production and rice farmers soon adopted its use for leveling fields. This technology employs automated dirt scoops that are pulled rapidly by large tractors. Laser signals from a set reference point are sent to the "bucket" of the dirt scoop and move it up or down depending on the elevation difference between points. By traveling over a field several times, the surface soil is moved throughout the field until all areas are the same elevation or a slight fall occurs from one side of the field to the other. This "grading" facilitates both storage and drainage of surface water in a field. When a field has been laser-leveled all seasonal wetlands and depressions are filled and natural patterns of surface water flow and runoff are disrupted. The exact area in the Grand Prairie that has been laser-leveled is unknown because no permits or records of leveling are required. We attempted to determine an estimate of the acreage of laser-leveled fields by interviewing contractors that conduct this work in the region, Natural Resources Conservation Service personnel in each county, staff of the White River Irrigation District, and local farmers and residents. Additionally, we conducted road-side surveys of fields in the region to identify fields where leveling had occurred. Recognizing the caveats of the information, we estimate that approximately 45,000 acres (18% of the current irrigated cropland) of the Grand Prairie has been laser-leveled (Fig. 25). The amount of laser leveling is increasing rapidly; we observed at least 10 fields being leveled in late spring 2000. We expect that nearly 25% of Grand Prairie fields will be laser-leveled within the next 2-3 years.

## **Wildlife Populations**

The exact number and abundance of wildlife species present in the Grand Prairie region during the early to mid-1800s are unknown. Early accounts of wildlife in the region usually are restricted to observations of large species and those that were sought for game and food. Furthermore, few systematic surveys of wildlife have occurred in Arkansas, especially prior to 1970. Data on birds are better than for other species because annual Christmas bird counts and U.S. Fish and Wildlife Service Breeding Bird surveys have been conducted in the last several decades. Because of this dearth of information we can only speculate on the magnitude of changes for most species.

The tremendous loss (>95%) of prairie, seasonal herbaceous wetlands, slash, and savanna habitats has caused most wildlife species primarily associated with these habitats to disappear or remain only in small remnant populations. Only a few prairie birds remain and include more cosmopolitan species that can adapt to pasture and haylands such as meadowlark, dickcissel, and several species of sparrow (Tables 4 and 9). Small rodents are common in the Grand Prairie but species composition has shifted from prairie species such as prairie dogs, weasels, marmots, ground squirrels, voles, and certain mice to granivorous and urban species such as mice and rats (Table 5). Raptor and birds of prey species in rice fields and other cropland, pasture, and open woodlands now are dominated by harriers, great horned owls, and red-tailed hawks instead of formerly abundant short-eared owls, burrowing owls, and prairie falcons. Prairie chickens have been extirpated from the region. No large herbivores are present today except white-tailed deer. Little is known about changes in amphibian and reptile populations in the region, but undoubtedly declines have occurred based on trends in similar areas in the southeastern U.S. (U.S. Geological Survey, unpublished report on "An outline of issues associated with amphibian declines").

Populations of many waterbirds in the prairie terrace part of the Grand Prairie region probably expanded in the early 1900s when seasonally flooded rice fields replaced grasslands and scattered seasonal herbaceous wetlands. Instead of having 3,000-6,000 acres of seasonal herbaceous wetlands prior to rice, this region had 100,000-150,000 acres of seasonally flooded rice fields by 1920. Species that bred in shallow emergent wetlands such as short-billed marsh wrens, blackbirds, king rails, and bitterns probably increased in the early 1900s when rice acreage increased greatly (e.g., Meanley 1969). Nonetheless, numbers of these species started to decline in the mid 1900s when rice production became more intensive. During this era, soil salinity increased, weeds (moist soil and emergent species) and invertebrate pests (aquatic insects) were reduced with

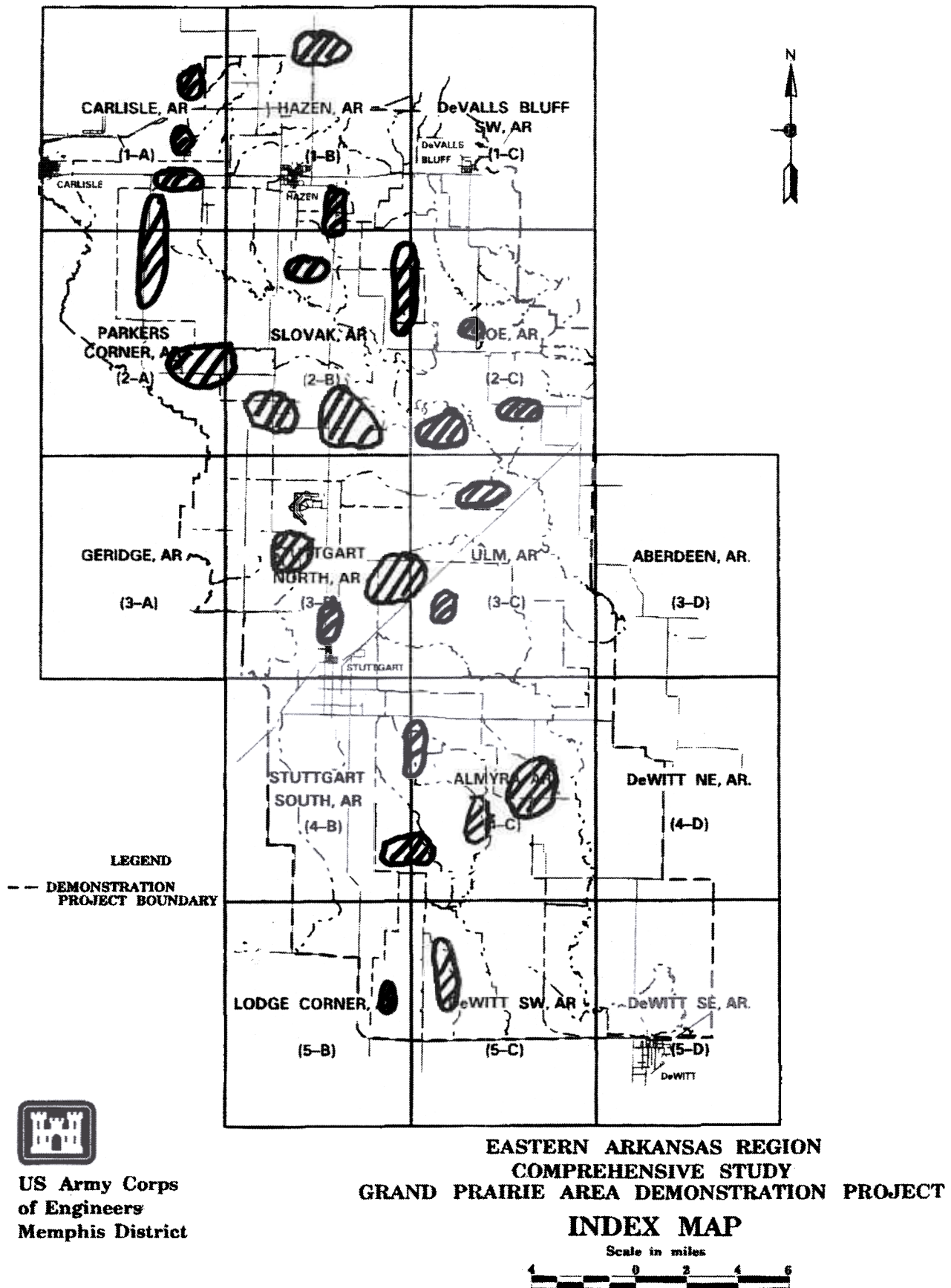


Figure 25. Locations within the Grand Prairie of Arkansas where laser-leveling of fields has occurred.

**TABLE 9.** Population trends for grassland birds and birds of management concern for U. S. Fish and Wildlife Service Region 4 that occur within the Grand Prairie region of Arkansas. Birds that only stop over in the Grand Prairie region during migration are excluded. CBC = Christmas Bird Count, BBS = Breeding Bird Survey, AR = Trends for Arkansas, MAP = Trends for the Mississippi Alluvial Plain, R4 = Trends for U.S. Fish and Wildlife Service Region 4, and US = Trends nationwide, \* =  $P < 0.05$ , \*\* =  $P < 0.01$ , NA = not applicable/available.

Species	Common Name	CBCAR	CBCUS	BBSAR	BBSMAP	BBSR4	BBSUS
<i>Botaurus lentiginosus</i>					NA		
<i>Haliaeetus leucocephalus</i>					NA		
<i>Ictinia mississippiensis</i>					-2.2		
<i>Circus cyaneus</i>					NA		
<i>Buteo jamaicensis</i>					14.6*		
<i>Falco sparverius</i>					6.7		
<i>Tympanuchus cupido</i>					NA		
<i>Colinus virginianus</i>					-3.2**		
<i>Rallus elegans</i>					-52.8		
<i>Gallinago gallinago</i>					NA		
<i>Scolopax minor</i>					NA		
<i>Sterna antillarum</i>					15.7		
<i>Athene cunicularia</i>					NA		
<i>Asio flammeus</i>					NA		
<i>Empidonax traillii</i>					NA		
<i>Tyrannus tyrannus</i>					-5		
<i>Tyrannus forficatus</i>					10.6		
<i>Lanius ludovicianus</i>					-0.9		
<i>Vireo bellii</i>					-28		
<i>Eremophila alpestris</i>					0.2		
<i>Cistothorus platensis</i>					NA		
<i>Anthus rubescens</i>					NA		
<i>Dendroica discolor</i>					-15.7		
<i>Geothlypis trichas</i>					-3.9**		
<i>Spizella arborea</i>					NA		
<i>Spizella pusilla</i>					-9.6**		
<i>Spizella passerina</i>					-2.9		
<i>Ammodramus savannarum</i>					-6.4		
<i>Ammodramus lecontei</i>					NA		
<i>Passerculus sandwichensis</i>					NA		
<i>Melospiza lincolni</i>					NA		
<i>Melospiza melodia</i>					3.2		
<i>Melospiza georgiana</i>					NA		
<i>Poecetes gramineus</i>					NA		
<i>Zonotrichia albicollis</i>					NA		
<i>Zonotrichia leucophrys</i>					NA		
<i>Calcarius lapponicus</i>					NA		
<i>Spiza americana</i>					2.6		
<i>Sturnella magna</i>					-1.7		
<i>Carduelis tristis</i>					6.1		

\*Federally threatened species

<sup>b</sup>Regionally extirpated species

<sup>c</sup>Federally endangered species

high use of herbicides and pesticides, fields were leveled, surrounding bottomland and terrace hardwood forests were cleared, and field edges were cleaned and ditched. One exception to declining marsh breeding birds was blackbirds, which continued to have very high populations up until recently.

Numbers of seasonally present waterbirds also increased when rice production exploded on the Grand Prairie, most notably certain species of waterfowl such as mallard, pintail, green-winged teal, white-fronted geese, and lesser snow geese. Waterfowl were abun-

dant in the region prior to rice production because of scattered prairie emergent wetlands and the nearby floodplains and associated wetlands and flood water of the White and Arkansas rivers and Meto, La Grue, Mill, Two Prairie and Wattensaw bayous (Howell 1911). The dynamics of winter flooding in bottomland hardwoods and the limitation of food in many winters caused historic populations of waterfowl in the MAV to use and rely on many different floodplains of the region (Fredrickson and Heitmeyer 1988). Waterfowl populations fluctuated among years in response to these

dynamics (Heitmeyer and Fredrickson 1981). Food was often limiting to wintering waterfowl populations and was mostly contained in bottomland hardwood habitats where acorns, seeds of moist soil plants and shrubs, and forest invertebrates occurred. When rice came to the Grand Prairie, a new abundant food source became readily available to waterfowl species capable of eating big seeds such as mallards, pintail, and geese. Early rice fields contained not only waste rice grain, but also seeds from weeds growing in the crop and aquatic invertebrates especially Chironomids. It is believed that as much as 20-30% of early 1900s rice crops were lost when fields had very inefficient harvest machinery or manual labor (Spicer 1964). As an example, if early rice fields produced on average 80-100 bushels rice/acre and 20% was lost, then 100,000 acres of rice land would have 16-20 million bushels of rice left in fields after harvest.

Early accounts of hunters and pioneers and records from duck clubs and local residents in the early 1900s suggest that waterfowl populations increased greatly in the Grand Prairie during the early 1900s, probably to their highest levels ever in the region (Bowman and Wright 1998). Subsequently, clearing of adjacent bottomland hardwood forests and alterations to floodplain hydrology and flood events, increased efficiency of rice production and harvest, decreased water available for and flooding of rice fields in winter, increased disturbance and hunting pressure, and expanded rice acreage elsewhere in the MAV have caused waterfowl numbers (with the exception of lesser snow geese) to decline significantly in the Grand Prairie. Peak duck populations in the area have declined from 2-3 million in the 1920s to 100,000-200,000 in the 1990s (unpublished USFWS and Arkansas Fish and Game Commission records).

Many native wildlife species in bottomland hardwood forests in the Grand Prairie region remain abundant, largely because of the connectivity to large remaining blocks of this habitat along the nearby White, Arkansas, and Mississippi river floodplains. As an example, black bears are still found in parts of the White River floodplain, including part of the Grand Prairie section of the river. This is one of the few remaining populations of bears left in the MAV. Other bottomland forested species of special note that have remnant (albeit reduced) populations include Swainson's, cerulean, and worm-eating warblers; several Tyrannid flycatchers; pileated woodpeckers; otters; alligator snapping turtles; and several endemic fish and mussels.

Fish populations in the Grand Prairie formerly were restricted to larger streams of the region and the larger rivers that border the area. An analysis of remnant fish populations (Killgore et al. 1998) indicates most populations have declined significantly in streams be-

cause they have become drier, intermittent, and with poorer water quality. While stream fishes have declined, new fish habitat now occurs in the numerous reservoirs in the area, and in certain stretches of streams that have been impounded by dams, weirs, and roads.

## ECOSYSTEM RESTORATION OPTIONS

The challenges to restore significant amounts of native habitats in the Grand Prairie region to a Presettlement condition are substantial and formidable. In many locations it is probably impossible to restore native habitats. Alterations to the Grand Prairie ecosystem are severe and summarized as:

1. Over 73% of all native habitats in the region have been lost, mostly to agricultural (rice) production.
2. Over 95% of prairie grasslands, seasonal herbaceous wetlands, slash, and savanna habitats have been destroyed.
3. Groundwater tables have declined by over 100' and annual extractions from the alluvial aquifer currently exceed recharge by 17%.
4. Subsurface flows now move from the White and Arkansas river floodplains toward the alluvial aquifer that underlies the Grand Prairie; a reverse from conditions present in the early 1900s.
5. Over 600 wells pump groundwater to irrigated crop fields; about 80 of these are "deep" wells that tap the Tertiary Sparta aquifer.
6. Over 300 reservoirs that cover over 15,000 acres capture and store surface water.
7. Most reservoirs and some well systems employ water pump-back and return systems to reuse and conserve surface water.
8. Fields that have historically relied on groundwater for irrigation have altered soil pH that is now more alkaline (up to 8.0).
9. An extensive system of roadside ditches, railroad ditches, irrigation conveyance ditches and pipelines, and urban ditches is present in nearly every prairie terrace section and in many floodplain areas.
10. Over 100 dams, weirs, siphons, and pumps divert and extract water from streams within and bordering the Grand Prairie. Flows are reduced in all streams, many now are intermittent, and winter/spring overbank flooding occurs only during large rain events.
11. Thousands of miles of small agricultural levees are present; many sections have up to 50 miles of internal field levees used to make water depths uniform in rice fields.

12. Almost all of the prairie terrace has a mile-square gridwork of roads and associated road crown and ditches around each section.
13. Over 95% of crop fields in the region are irrigated and almost all irrigated fields have been leveled to some extent with land planes and floats.
14. Approximately 45,000 acres (18%) of irrigated fields have been laser-leveled; up to 25% may be leveled within the next 2-3 years.
15. Populations of almost all wildlife species endemic to the area are greatly reduced and certain species are extirpated.
16. Numbers of certain waterfowl (especially mallards) and icterids are higher than during resettlement periods, but have declined significantly in the last 2 decades.

### Guiding Principles

Our assessment of potential options for restoring native habitats in the Grand Prairie region is based on the fundamental belief that first we must understand what the ecosystem looked like and how it functioned at some base reference time (in this case the mid-1800s) and then understand what has changed in the system since that time. We have done that above. Now, we suggest that the following basic principles guide analyses and decisions about restoration options:

#### What is the Appropriate Conservation Objective?

Conservation strategies that are most appropriate for a given site depend on the degree the physical nature and ecological processes of the site have been altered or degraded (Fig. 26). In locations where both the structure (e.g., plant species composition, topography) and processes (e.g., fire, seasonal flooding, herbivory) of native habitats are relatively intact, then protection of the site is needed first, and then some enhancement of alterations may be required. Despite extreme loss of habitats in the Grand Prairie, a few sites remain relatively unaltered and need protection. These include bottomland hardwood forests along the White River floodplain.

Where the physical features of a site are badly altered (e.g., deforestation), but the processes are still present (e.g., shallow seasonal flooding), then restoration of the altered structure and perhaps enhancement of process is needed. An example of this situation in the Grand Prairie is the deforested floodplain along the lower La Grue Bayou where reforestation and some enhancement of winter flooding is needed. Conversely, where physical aspects of a site are intact (e.g., undulating prairie grassland), but the processes have been

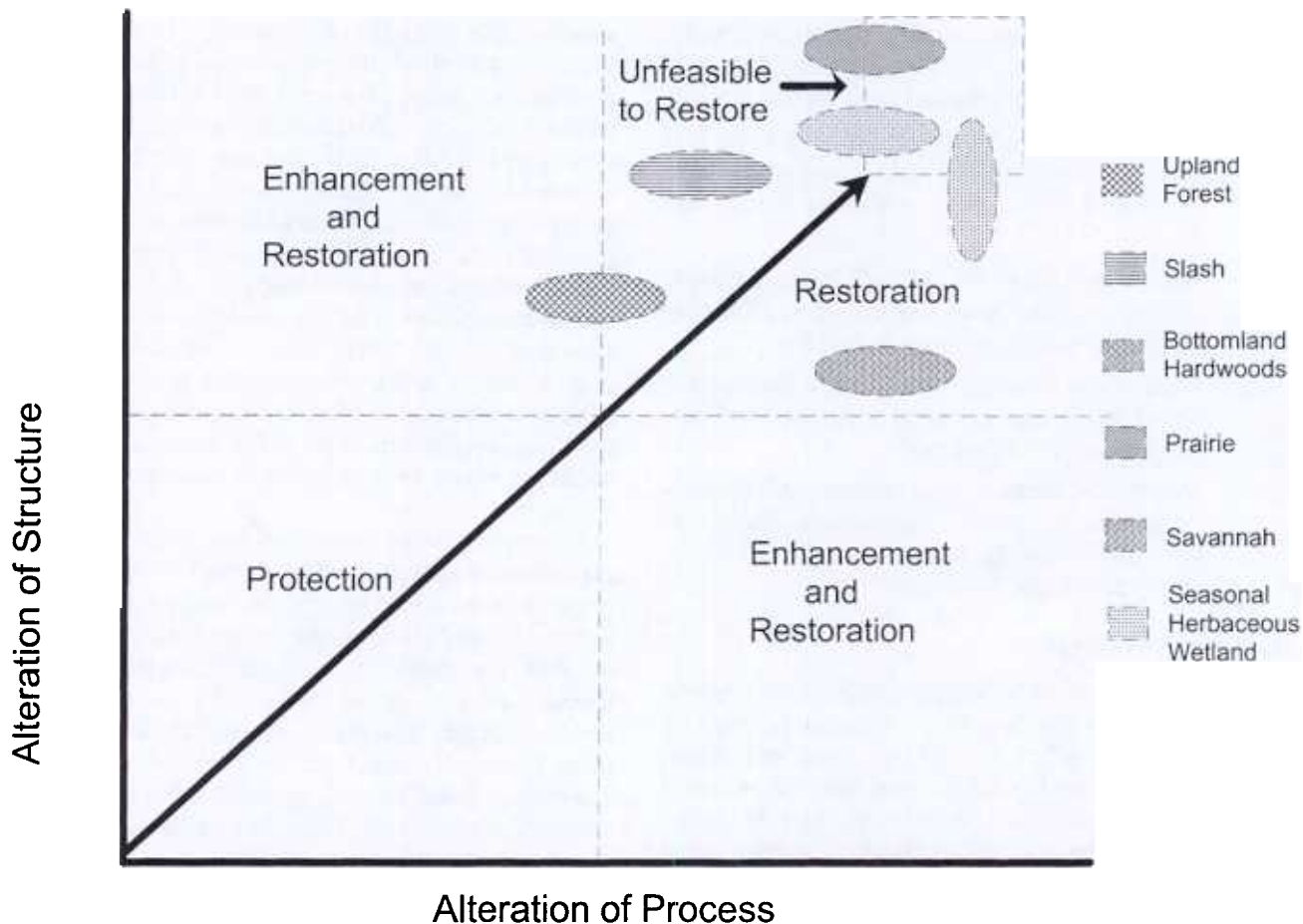
eliminated (e.g., no fire, disrupted overland sheetflow) then restoration of the process and enhancement of structure are required. An example of this case would be the small isolated patches of prairie grasslands and slash that still exist. Here, fire and sheetflow must be restored to maintain grassland and shrub species. Finally, when both the physical context and ecological processes of a location have been significantly altered, the only remaining conservation option is full restoration of both structure and process if restoration is possible at all (Berger 1990). When conditions are extreme (e.g., a ditched and leveled soybean field) restoration options are limited. Unfortunately, many locations on the Grand Prairie terrace are in this extremely degraded condition where restoration would be extremely difficult at best.

In general, prairie grasslands and seasonal wetlands are the most altered habitats in the Grand Prairie region. Savanna and slash also are badly degraded, but in some limited cases, slash habitats retain at least some remnant processes (e.g., slight drainage headcuts). Bottomland and terrace hardwood forests are less altered physically than the above habitats and at least in some locations retain both structure and less altered processes. Upland habitats probably are in the best situation (albeit poor) of Grand Prairie habitats. Once a site is restored, the intensity of management required to maintain the habitat increases with the degree of alteration (Fig. 26).

#### Like-for-Like

If restoration of a site is the appropriate conservation action, then the restored ecosystem "type" should match what was previously present (related to the base reference period). Simply put, habitats should not be "created" where they were not present previously. Prairie restoration should occur where original prairie was and similarly for other habitats. The attempt to understand what Presettlement habitat composition and distribution of the Grand Prairie region during the mid-1800s provides this base, and first-level decision, for prioritizing restoration in the region. Creation of habitats where they were not previously present may have a role in conservation actions in the Grand Prairie, but they do not constitute "restoration," nor is it likely that they can achieve sustainable structure and process without significant and costly manipulations, physical alterations, and future management.

It is important to understand that landscapes (such as the Grand Prairie region) are mosaics of interspersed habitats and that often subtle changes in topography, climate, or disturbance can cause more than one habitat type to occur within a small area. Furthermore, habitat patches are dynamic temporally, especially where regular or episodic disturbance (such as fire, flooding,



**Figure 26.** Model of the conservation actions most appropriate, and intensity of future management required, on sites of varying amounts of alteration of Presettlement physical condition and ecological processes in the Grand Prairie of Arkansas.

etc.) occurs. The Grand Prairie ecosystem historically was dynamic, and the “edges” of major habitat zones were in regular flux. In these “edge” areas, it may be possible (and desirable) to restore more than one habitat type. An example of such an “edge” is the area near the Prairie Bayou Wildlife Management Area which probably was prairie during the Altithermal period, gradually was invaded by woody species, likely became savanna 1,000-2,000 BP, and eventually became terrace hardwood forest by the mid-1800s. Soils and topography in this site potentially are conducive to restoration of all of the above habitats.

### Structure and Function

Structure (i.e., the physical makeup of plant and animal communities, topography, soils, juxtaposition of habitats) and function (i.e., regulatory processes of fire, flooding, nutrient cycling, breeding habitat for organisms) are multi-scaled ecosystem attributes that must be understood prior to restoration activities. Restoring structure (e.g., removing crops and planting

prairie grasses, reforesting formerly cleared lands) without restoring processes (e.g., fire, sheetflow) will result in only a temporary shift to historic communities, because current processes will lead to plant and animal communities that can differ dramatically from the target communities.

In some cases, restoration of both structure and process may not be possible. Many such situations exist in the Grand Prairie region. Land-leveled and highly ditched terrace fields that formerly were prairie grassland, are one example. In this case, partial restoration of ecosystem structure (e.g., planting prairie grass) is possible, but restoring micro topography and removing ditches are not feasible. Thus, the site initially would have prairie plant communities, but these communities would not be sustainable nor would they function like historic prairie communities.

### Landscape Ecology

The structure and function of ecosystems varies across spatial scales. At a specific site, restoration of

plant community composition and regulatory processes (e.g., fire, micro topography) will require immediate on-site modifications. In contrast, at broader spatial scales, the size, shape, degree of isolation, and connectivity to other habitats are important “landscape ecology” features that must be considered and understood to successfully restore ecosystem structure and function. Functional ecosystems are composite “land mosaics” of different habitats positioned together in a specific way to retain the complex and interacting productivity and biodiversity of a region.

In the Grand Prairie region, the basic landscape contexts of the different habitats vary in relation to size, connectivity, etc. (Tables 7 and 10). Generally, prairie, bottomland and terrace hardwood forests, and upland forests historically were present in large blocks that had high within-habitat connectivity. Savanna habitats were medium in size and were moderately connected to other savanna habitats. Seasonal herbaceous wetlands and slashes were small and unconnected to similar habitats. Restoration options and opportunities for these smaller, unconnected habitat types are more abundant and less expensive than restoring large blocks of habitats. It is important to consider, however, that while these habitat types historically were isolated from other similar habitats, they were embedded in a matrix of prairie and forests. Many organisms utilizing seasonal herbaceous wetlands and slashes require adjoining habitats to meet life-history requirements. Thus, restoring small isolated wetlands or slashes without restoring adjoining habitats will provide limited benefits to some species.

The appropriate spatial scale of restoration activities depends on specific objectives of the work and the organisms of interest (Table 10). Generally, it is assumed that if restoration objectives are focused on species that require larger blocks of habitat (e.g., prairie chickens, Henslow sparrow) then populations of species that do not need big areas of habitat (e.g., prairie vole) also will be supported. However, simply “restoring” large blocks of habitat without consideration of the types of habitat, the juxtaposition and connectivity of habitats, and life-history needs and mobility of species will minimize the success of the restoration effort. Conversely, restoring structure and function (e.g., hydrology to a former slash area) to small isolated habitats may be of little value to species that require larger interconnected habitats.

### Practicality

Attempts to restore habitats in any region, must include an honest “reality check” to determine the practicality of actually restoring a specific habitat type or location. The practicality of restoring an area depends on how degraded the structure and functions of a loca-

tion are, the probability of obtaining access or ownership to a site, costs of restoration activities, and the level of management intensity that will be required to sustain the habitat once restored. Whether we like it or not, some landscapes are so highly altered (Fig. 26) that restoration simply is impossible or the social and financial costs so high that restoration should not be attempted on that site. Many locations on the Grand Prairie are in this situation including: 1) prairie terrace areas that are laced with roads, ditches, wells, and laser-leveled fields; 2) bottomland floodplain areas that have been deforested, displaced with reservoirs, and have reduced and highly changed streamflow and flood events; and 3) upland forested hills that have been cleared, leveled, dammed with reservoirs and fish ponds, and fragmented with numerous dwellings.

### Management Intensity

The intensity of management that will be required to sustain a restored site is directly related to how degraded the site was prior to restoration (Fig. 26), to the size of the restored site relative to habitat landscape needs (Table 7), and to success of the restoration of ecological processes. In locations where the processes are mostly restored with natural occurrences (e.g., overbank winter flooding, overland sheetflow, etc.) the subsequent management required will be minimal. Where natural processes cannot be fully restored or are undesirable (e.g., wildfires) then more intense management will be required. In general, the small unconnected habitats such as seasonal wetlands and slash will be easiest to manage if sheetflow can be maintained or restored in the small watershed leading to these habitats. In contrast, small isolated prairie habitats will require significant and regular management to recycle litter and retard encroachment by woody vegetation.

### Limits and Threats

Various interest groups will have different priorities about: 1) which habitats are most important to be restored; 2) how large an area is desirable for restoration and which land use practices must be changed; 3) where the restorations should be related to ownership, jurisdictions, and financial responsibility; and 4) who will be responsible for conducting restoration, monitoring, and managing the restored habitat. One way to consolidate the various interests is an agreement to assess which habitat types and locations are most limiting for the long-term sustainability of ecosystem function (e.g., protection of adequate surface water) and species of concern (e.g., mallards) and which habitats and locations are in the most threat of being further degraded and becoming unsustainable (e.g., the cone of depression of the underlying alluvial aquifer).

**TABLE 10A.** Seasonal Herbaceous Wetlands in the Grand Prairie Region of Arkansas and the relationships among ecological principles, landscape configuration, patch size, economic costs, and the implications for management and restoration.

Landscape configuration	Patch size	Ecological principles or condition	Economic costs	Management and restoration implications
	Small		Low	Habitat for many amphibians and reptiles limited because connectivity to terrestrial habitats is modified.  Changes in historical surface and subsurface hydrology modify current hydroperiod.
Isolated from other seasonal wetlands	Small	Modification or removal of native plant communities.	Low	Increased potential for high sedimentation rates  Historic foods no longer available  Invasion of exotic plants and animals
Isolated from other seasonal wetlands	Small	Connectivity	Low	Long-term viability of amphibian populations limited due to isolation from other populations  Waterbird use limited if local wetland availability is reduced
Connected to other habitats of the Grand Prairie	Small	Connectivity	High	Small Wetland area may limit use by some species.  High densities of small wetlands within an area will increase overall habitat value for wetland dependent species since other required habitats are closely juxtaposed.  Connectivity to terrestrial matrix increases habitat value for many reptiles.  Local habitat features of the individual wetland will also influence overall wildlife use.
Connected to other habitats	Small	Habitat Mosaic	High	Small wetland area may limit use by some species.  High densities of small wetlands within an area will increase overall habitat value for wetland dependent species, other required habitats are closely juxtaposed.  Connectivity to terrestrial matrix increases habitat value for many amphibians and reptiles.  Local habitat features of the individual wetland will also influence overall wildlife use.
Isolated from other seasonal wetlands	Large	Connectivity	Moderate	1) Surrounding land use is important in determining overall habitat value.
Connected to other habitats	Large	Connectivity	High	1) Large wetlands with diverse habitats can provide predictable benefits for wetland dependent wildlife.

**TABLE 10B.** Prairie in the Grand Prairie Region of Arkansas and the relationships among ecological principles, landscape configuration, patch size, economic costs, and the implications for management and restoration.

Landscape configuration	Patch size	Ecological principles or condition	Economic costs	Management and restoration implications
Isolated			Low	Limited habitat value for most wildlife  Maintain remnant plant populations
Along canal banks	Large but linear	Connectivity	Low-High	Connectivity can enhance genetic diversity of plants Limited value for most wildlife species  Soils, hydrology, and other ecosystem processes may differ from historic conditions, thus maintenance costs could be high.  Potential travel lanes for predators or corridors for management between remnant or restored prairie tracts
Along canal banks	Large but linear	Modification of historic habitat mosaic	Low-High	Potential to reconnect different habitat types
Connected to other habitats	Large	Connectivity	High	Can provide habitat for a variety of wildlife species  Can help maintain high levels of genetic diversity of plants and animals
Connected to other habitats	Large	Modification of historic habitat mosaic	High	In an agricultural matrix as large as the Grand Prairie, even large tracts (>1000 acres) may still not be large enough to support successful breeding populations of some species

We suggest that a simple model (modified from Heitmeyer 1994:9) of limitations and threats be used to prioritize restoration actions in the Grand Prairie (Fig. 27). Sites and habitats that are both limiting to the Grand Prairie ecosystem and that are threatened with further degradation would receive highest priority and conversely, sites that are less limiting and perhaps not highly threatened would receive the lowest priority for restoration. Furthermore, within each priority category, priority should be given to restorations that:

- work in areas with the most important ecological processes; i.e., seasonally available surface water
- work in areas with the highest diversity of species of concern; i.e., prairie and bottomland and terrace hardwood forests
- work in areas with the most severe limitations (where feasible - see #5 above)

Also, generally, restoration actions should be favored that:

- are not being adequately addressed by other entities; i.e., on land not currently being managed for conservation purposes
- offer long-term solutions and in larger connected blocks
- everything being equal, provide the greatest multi-species benefits
- do not harm threatened or endangered species
- provide maximum benefits for minimum long-term costs, given options available

### Restoration Decisions

Entities interested in restoring habitats in the Grand Prairie region likely will have different priorities and objectives for specific locations and habitat types. This document cannot decide those objectives but identifi-

**TABLE 10C.** Slash in the Grand Prairie Region of Arkansas and the relationships among ecological principles, landscape configuration, patch size, economic costs, and the implications for management and restoration.

Landscape configuration	Patch size	Ecological principles or condition	Economic costs	Management and restoration implications
Isolated	Small		Low	Difficult to maintain representative vertebrate populations
Isolated from or connected to other slash	Small	Modification of	Low-High	Limited potential to maintain historic wildlife Distribution and abundance of historic food and cover reduced.
Connected to other slash	Small	Connectivity	Low	Potential to protect rare plants. Difficult to maintain representative vertebrate populations.
Isolated from or connected to other habitats	Small-Large-	Modification of historic processes	Low-High	Difficult or impossible to maintain historic plant community composition and structure Difficult to meet life history requirements of historic wildlife population Presence of exotic plants and animals likely
Isolated from other slash	Large	Connectivity	Moderate	Potential to protect rare plants. Needs of some individuals met but difficult to maintain animal populations
Connected to other slash	Large	Connectivity	High	Potential to meet population needs of small animals. Potential to have viable plant community.

**TABLE 10D.** Upland Forest in the Grand Prairie Region of Arkansas and the relationships among ecological principles, landscape configuration, patch size, economic costs, and the implications for management and restoration.

Landscape configuration	Patch size	Ecological principles or condition	Economic costs	Management and restoration implications
Isolated from other upland forest patches			Low	Difficult to maintain representative vertebrate populations
Connected to other Grand Prairie habitats	Small	Connectivity	Low	Populations difficult to maintain
Isolated from or connected to other upland forest	Small-Large	Modification of historic processes	Low-High	Limited potential to maintain historic wildlife Exotics often invasive
Isolated from or connected to other Grand Prairie habitats	Small-Large	Modification of historic processes	Low-High	Difficult or impossible to maintain historic plant community composition and structure Presence of exotic plants and animals likely
Isolated from other upland forest patches	Large	Connectivity	Moderate	Potential to protect rare plants Individual needs met but populations difficult to maintain

**TABLE 10E.** Terrace Hardwood Forest in the Grand Prairie Region of Arkansas and the relationships among ecological principles, landscape configuration, patch size, economic costs, and the implications for management and restoration.

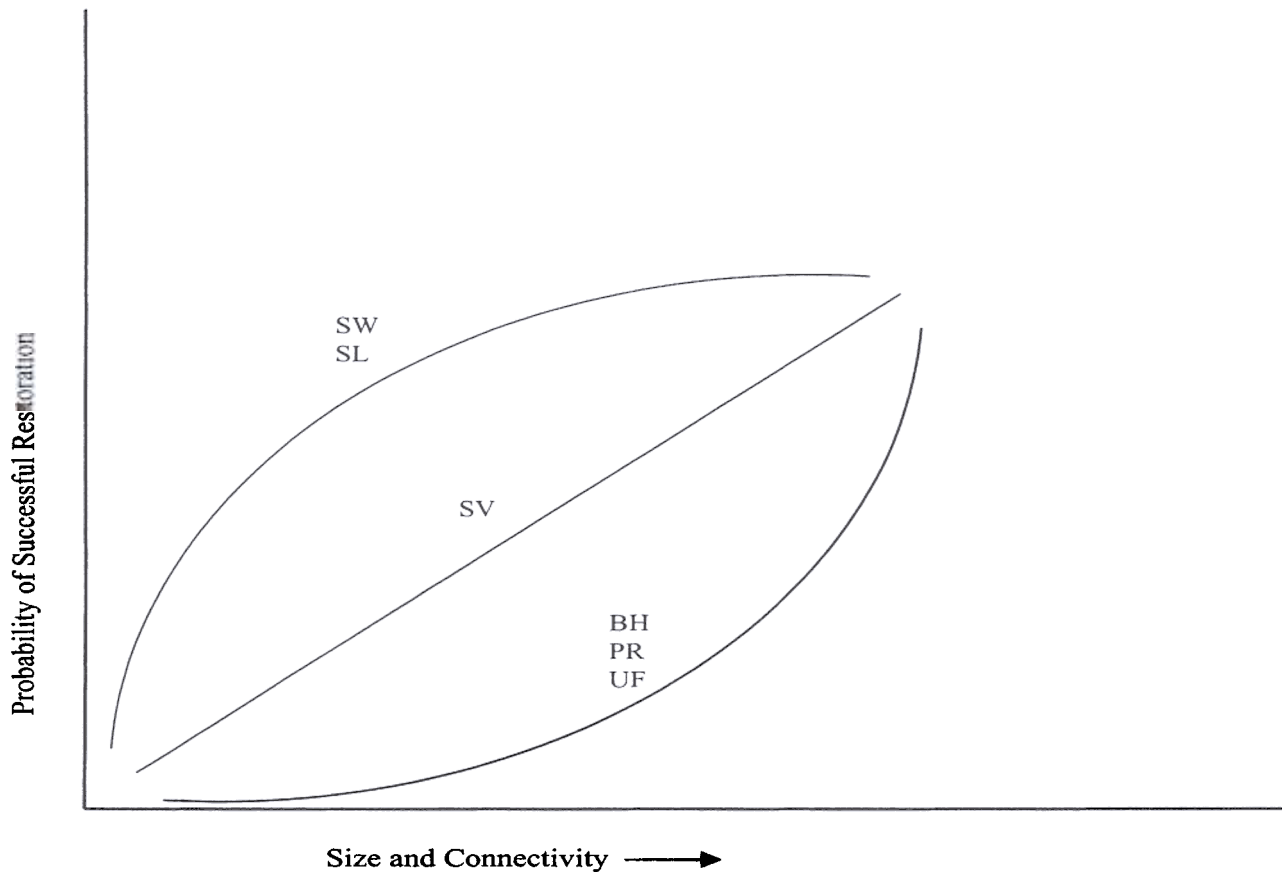
Landscape configuration	Patch size	Ecological principles or condition	Economic costs	Management and restoration implications
Isolated from or connected to other Terrace Hardwoods	Small		Low	Difficult to maintain representative vertebrate populations
Isolated from or connected to other terrace forest	Small-Large	Modification of historic processes	Low-High	Limited potential to maintain historic wildlife. Exotics likely to invade.
Isolated from or connected to other Grand Prairie habitats	Small-Large	Modification of historic processes	Low-High	Exotic plants or animals likely Difficult or impossible to maintain historic plant community
Isolated from or connected to other Terrace Hardwoods	Large	Connectivity	Moderate	Potential to protect rare plants

**TABLE 10F.** Bottomland Hardwood Forest in the Grand Prairie Region of Arkansas and the relationships among ecological principles, landscape configuration, patch size, economic costs, and the implications for management and restoration.

Landscape configuration	Patch size	Ecological principles or condition	Economic costs	Management and restoration implications
Isolated from or connected to other Bottomland Hardwood Forests	Small	Connectivity	Low	Difficult to maintain representative vertebrate populations
Isolated from or connected to other Bottomland Hardwood Forests	Small	Connectivity	Low	Single climatic or management events may affect the entire area
Isolated from or connected to other Grand Prairie habitats	Small-Large	Connectivity	Low-High	Needs of individual populations difficult to maintain
Isolated or connected to Grand Prairie habitats	Small-Large	Modification of historic processes	Low-High	Limited potential to maintain historic other wildlife
Isolated from or connected to other Grand Prairie habitats	Small-Large	Modification of historic processes	Low-High	Exotic plants and animals likely present Monotypic vegetation likely to develop
Isolated from or connected to other Bottomland Hardwood Forests	Large	Connectivity	Moderate	Individual needs met but size inadequate for population.

**TABLE 10G.** Savanna in the Grand Prairie Region of Arkansas and the relationships among ecological principles, landscape configuration, patch size, economic costs, and the implications for management and restoration.

Landscape configuration	Patch size	Ecological principles or condition	Economic costs	Management and restoration implications
Isolated from or connected to other Savanna habitats		Connectivity	Low	Difficult to maintain representative vertebrate populations
Connected to other habitats	Small-Large	Connectivity	Moderate	Potential to protect rare plants, needs of individuals met but population difficult to maintain
Isolated from or connected to other terrace forest	Small-Large	Modification of historic vegetation	Low-High	Limited potential to maintain historic wildlife. Exotics likely to invade.
Isolated from or connected to other habitats	Small-Large	Modification of historic processes	Low-High	Exotic plants or animals likely Difficult or impossible to maintain historic plant community
Isolated from or connected to other Savanna habitats	Large	Connectivity	Moderate	Potential to protect rare plants. Needs of individuals met but populations difficult to maintain



**Figure 27.** Priority categories of habitat restoration efforts in the Grand Prairie of Arkansas in relationship to future threat of loss or degradation and limitation to ecosystem function and species of concern. SW=seasonal herbaceous wetlands, SL-slash, SV-savanna, BH=bottomland hardwood forest, PR=prairie grassland, UF= upland forest.

cation of the landscape and ecological characteristics that are needed at a site to successfully restore specific habitats is possible (Table 11). We also offer thoughts on the relative difficulty of restoring each habitat, and in which landscape contexts restorations are most likely to succeed.

**TABLE 11.** Ecological attributes that are required to successfully restore habitats in the Grand Prairie region of Arkansas.

Habitat Type	Attribute
	<ul style="list-style-type: none"> <li>- High elevation terrace</li> <li>- Crowley, Calloway, Stuttgart soils</li> <li>- Gently undulating topography</li> <li>- Few dissecting drainages</li> <li>- Large patches, high connectivity</li> </ul>
Seasonal Herbaceous Wetland	<ul style="list-style-type: none"> <li>- Within prairie grasslands</li> <li>- Crowley, Calloway, Stuttgart soils</li> <li>- Shallow isolated depressions</li> <li>- Small watersheds with slow overland sheet flow</li> </ul>
Slash	<ul style="list-style-type: none"> <li>- Upper (head) end of drainages into prairie terrace</li> <li>- Stuttgart, Calloway soils</li> <li>- Spring-summer surface water runoff</li> <li>- narrow linear bands of shrubs next to drainages</li> <li>- not connected to other slash</li> </ul>
Savanna	<ul style="list-style-type: none"> <li>- transition zone from prairie to forest</li> <li>- Stuttgart, Calloway, Calhoun soils</li> <li>- Undulating topography, gentle slopes</li> <li>- Variable size, often parallel to terraces, ridges, and drainages</li> </ul>
Upland Forest	<ul style="list-style-type: none"> <li>- dissected hills and bluffs with good drainage</li> <li>- Various upland soils including Hebet, Midland, Perry, Grenada, McKamie</li> <li>- Variable size wherever bluffs and sharp topographic relief occurs</li> </ul>
Bottomland and Terrace Hardwood Forest	<ul style="list-style-type: none"> <li>- Floodplains of streams, larger depressions in terrace</li> <li>- Primarily Tichnor soils</li> <li>- Presence of surface water for extended periods winter-spring</li> <li>- Usually larger corridors along drainages, high connectivity</li> </ul>

## Prairie Grasslands

Prairie restorations should be attempted only on sites that previously were prairie during the Presettlement period. We recognize that a larger portion of the Grand Prairie was prairie prior to the 1800s, but changes in soils, hydrology, and climate eventually caused forest to encroach into these areas and make prairie restoration more difficult, if not impossible. Prairie locations during the Presettlement period were higher elevation terraces with Crowley, Stuttgart, and Calloway soils with <1% slope. Prairie lands had gently undulating topography, contained few drainages, and most grasslands were large and interconnected. Currently, only a few small remnant patches of native prairie remain and most of these are protected. Consequently, restoration is the only conservation option available to provide a significant prairie grassland component to the Grand Prairie landscape. Because the prairie was such a large part of the Presettlement region, and has been nearly completely destroyed, we believe restoration of prairie should be among the highest conservation priorities for the region.

Specifically, we encourage prairie restorations that:

- are on Crowley soils above 210'
- are at least 100 acres and preferably at least 1/4 mile wide (see Helzer and Jelinski 1999)
- enlarge existing patches of prairie
- restore prairie within 2-3 miles of another patch
- are not on laser-leveled fields
- can be actively managed with fire, plantings, and perhaps grazing
- are owned, managed, or controlled by a conservation entity
- are not heavily ditched and where existing ditches can be filled or removed

Restoration of large blocks of prairie in the Grand Prairie region will be difficult because of the great alterations to the prairie terrace, competing demands for land, and control and management of surface water. Furthermore, the cost of converting agricultural land to prairie and the level of management intensity that will be required to maintain prairie patches will be high. Nonetheless, restoring at least a few larger patches will help the Grand Prairie ecosystem to regain part of its ecological values and functions. We generally believe the area of greatest potential success for prairie restoration includes the highest elevations on the top center of the original prairie terrace, especially in the northern part of the region. Non-cropland areas that offer some potential for restoration include pasture, hayland, field borders, and railroad rights-of-way. We discourage attempts to restore prairie immediately adjacent to, or in, former (or current) forested areas because

soil types, surface water drainage, and irrigation will favor encroachment by trees and compromise long-term sustainability of the prairie.

### Seasonal Herbaceous Wetlands

Seasonal herbaceous wetlands were not abundant in the Grand Prairie region during Presettlement times and were confined to small shallow depressions within prairie grasslands. Few of these seasonal basins are left, and those that remain have greatly altered hydrology. Remnant herbaceous wetland basins should be protected and restored if possible. We encourage restoration of these wetlands wherever prairie grasslands are restored, specifically in prairie locations that:

- have more sloping topography and small depressions
- have few ditches, levees, or roads that disrupt overland sheetflow into the basins
- are distant from forest patches
- represent former meander scars of the Arkansas River in the prairie terrace

Fortunately, restored seasonal herbaceous wetlands do not have to be large or connected to other wetlands to be functional (Galatowitsch and van der Valk 1994). However, many seasonal basins present within a several square mile area is more desirable than many scattered basins. Consequently, we encourage restoration of many small basins within an area rather than a few large ones. These small basins can occur in some non-prairie areas but more intensive management will be required to maintain them as herbaceous wetlands because locations that are appropriate for restoration will have altered surface hydrology. Excavation of some basins may be possible, but if so, a method of controlling water will be required. Off-channel areas associated with non-floodplain reservoir return systems, irrigation canals, and ditches may offer limited opportunity for developing seasonal wetlands.

### Slash

Slash habitats were associations of pioneering plant species that occurred at the upper ends of drainages that extended into the prairie terrace. Sites that are most favorable for restoring slash are in the upper head ends of drainages and usually have Stuttgart or Calloway soils with >2% slopes. The watersheds that create the drainage are not leveled and receive at least some surface water runoff during spring and summer. Because slash habitats were dynamic in location, their size was small and vegetation was usually tolerant of wider ranges of hydrological and soil conditions. These features make restoration of slash potentially easier than either pure prairie or forested habitats (Fig. 28). We specifically encourage restoration of slash where:

- drainages, including ditches and canals, extend into higher elevation terraces
- non-leveled lands border drainages and field edges
- seasonal surface water is routed through drainages

Although few remnant patches of slash remain in the Grand Prairie, we generally believe this habitat may be the easiest to restore of all native habitats. The locations where slash can be restored not only include the heads of each natural drainage in the region, but also along the extensive ditches, canals, and reservoir return systems in the area. Many of these latter sites will be small and narrow, but nonetheless will add significant diversity to the region and generally not require intensive or regular management once invading woody species are established.

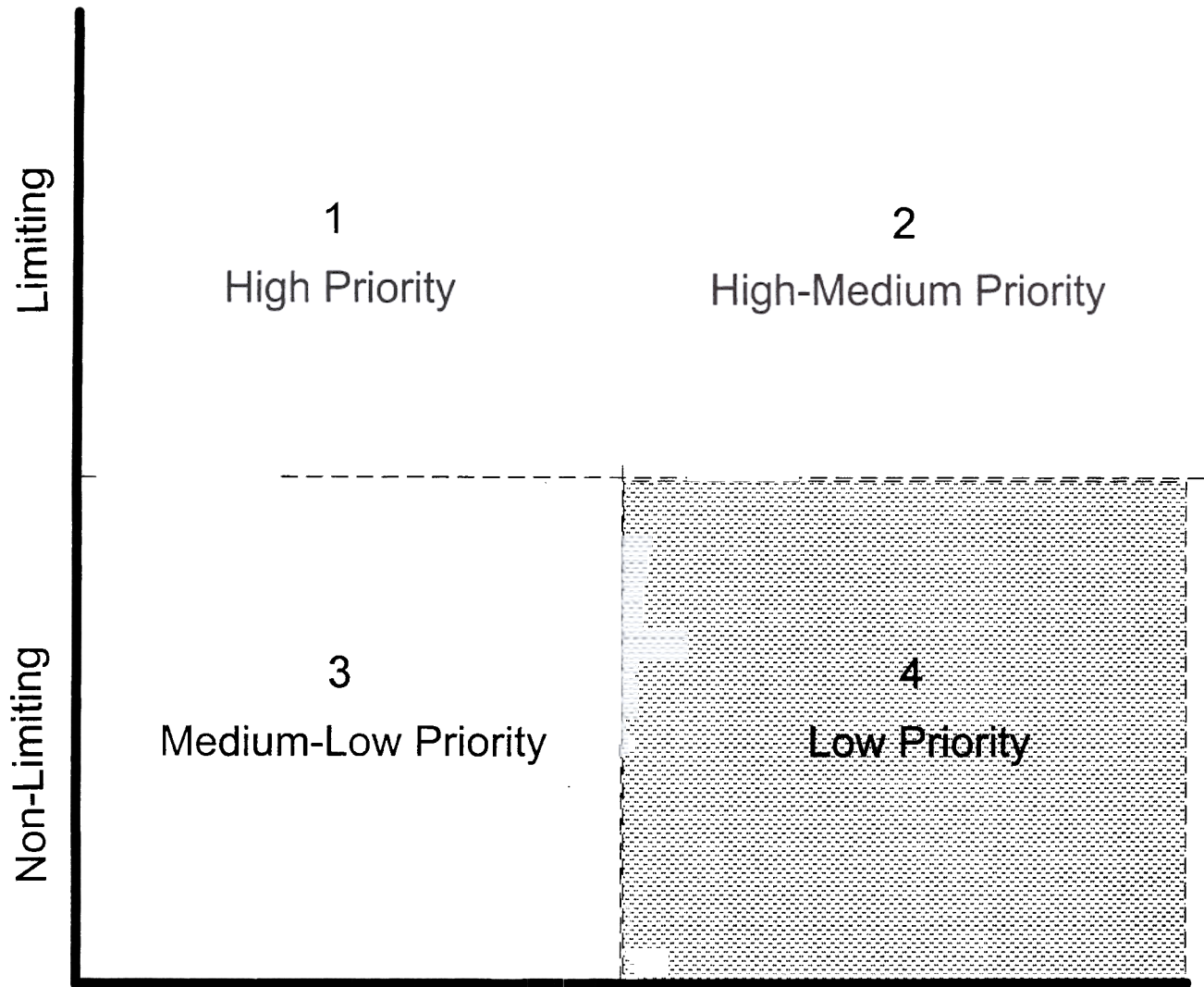
### Savanna

The ecological factors that created savanna habitats were actively competing forces that sustained relatively equal amounts of prairie grasslands (fire, tight clay soils, herbivory) and forest expansion (drainage, erosion of soils, ponding of surface water for extended periods). Consequently, restoration of savannas will be complex and may require contradictory management strategies. Few savannas remain in the Grand Prairie region. Interestingly, most remnant savannas occur near dwellings or towns on the edge of the prairie terrace where some sort of regular disturbance maintains at least a 50:50 mix of grass and trees. The disturbance factors that are most common include grazing, burning, mowing, and cutting.

We generally believe restoration of significant areas of savanna in the Grand Prairie region will be difficult except where humans regularly disturb grassland sites because natural disturbance factors are absent or undesirable to restore (e.g., wildfires). The best locations to restore savanna appear to be:

- on Stuttgart, Calloway, Loring, and Calhoun soils with 1-3% slopes
- near the edges of towns or farmsteads
- in pastureland
- at the ecotone of former prairie grasslands

Savannas present in the Grand Prairie during the 1800s apparently were not large and most patches were not immediately connected to each other. Consequently, restoration of savanna in the region should look for opportunities that meet the above characteristics regardless of how small they may be or their location relative to another savanna patch. While not optimal for restoring the animal community associated with savanna, these small restored sites will supplement the overall diversity and nutrient flow of the region.



**Figure 28.** Probability of successfully restoring habitats in the Grand Prairie of Arkansas in relationship to the size and connectivity of the restored site. SW=seasonal herbaceous wetlands, SL=slash, SV=savanna, BH=bottomland hardwood forest, PR=prairie grassland, UF=upland forest.

### Upland Forests

About 50% of Presettlement upland forests have been cleared; the remaining tracts are mostly in dissected hills and bluffs along drainages. About 1,500 acres of upland-type forests also have been planted on CRP lands in the region, but unfortunately most is non-native loblolly pine. Restoration of upland forest should target areas that formerly were upland forests and that are adjacent to existing patches. Several soil types support upland forests including Hebert, Midland, Grenada, Perry, and McKamie. We specifically encourage restoration of upland forests on sites that:

- have substantial topographic relief, including edges of floodplains
- are adjacent to larger blocks of upland forests such as the Wattensaw Wildlife Management Area and bluffs along the White River

- CRP lands that formerly were upland forests

While a policy issue, we discourage planting pine and other non-native tree species on CRP lands in the region. Vegetation in CRP fields should match the habitat type present during the Presettlement period. Consequently, not all CRP lands should have the same vegetation community. If prairie historically was present then prairie grasslands or a savanna vegetation should be promoted, and if forest was present then either upland, bottomland hardwood, or terrace hardwood forests should be restored on CRP lands.

Generally, less upland forest has been lost in the Grand Prairie region compared to other habitats. Furthermore, most upland forest that has been cleared has not been leveled and fewer ditches and roads have been built in these areas. An exception to this moderate physical alteration are the numerous aquaculture ponds

that are present in the northeastern part of the region south of De Valls Bluff. Restoration of upland forests will be easier where physical alteration of former upland forests is minimum, and restoration may simply require abandonment or some planting of appropriate tree species. While restoration of upland forests may be easier than most other Grand Prairie habitats, we do not believe it should be as high a priority because significant amounts of upland forest remain, and most remnant areas are not in imminent threat of destruction.

### Bottomland and Terrace Hardwood Forests

Bottomland hardwood forests covered more area of the Grand Prairie region than any other habitat type in the mid-1800s. While only 50% of the original 358,000 acres of bottomland forests have been lost in the entire region, over 83% of bottomland forests have been lost in the Grand Prairie Area Demonstration Project area. The amount of loss and its importance to floodplain and regional hydrology functions makes restoration of bottomland hardwood forests a high priority. Furthermore, remaining patches of bottomland forests in the Demonstration Project area are threatened by continued diversion of water from stream watersheds, continued conversion to reservoirs, mismanagement of greentree reservoirs, and poor timber management.

We encourage restoration of bottomland forests:

- within floodplains of all regional streams
- adjacent to existing patches of bottomland forests and where isolated patches can be connected
- in Tichnor soils
- where surface water is present (or can be provided) for extended periods during winter and spring
- in small watersheds that have few ditches and roads and that retain some overland sheetflow

A higher percentage of historic terrace hardwood forests has been lost in the Grand Prairie region compared to bottomland hardwood forests. Specifically, within the Demonstration Project area, over 90% of Presettlement terrace forest has been cleared and drained. Terrace hardwoods historically were present in more isolated locations and flats in the prairie terrace and have been converted to reservoirs and agricultural crops. The hydrology of terrace hardwoods is driven more by overland sheetflow and extended soil saturation as opposed to overbank flooding and extended seasonal inundation of bottomland hardwoods. These hydrological attributes are more difficult to restore, given the significant alteration of topography and hydrology on the prairie terrace. The best remaining terrace hardwoods are on duck hunting club properties.

We encourage restoration of terrace hardwoods:

- in historic prairie terrace flats and depressions

that have not been land-leveled

- in Tichnor and Calhoun soils
- adjacent to remnant patches of terrace hardwoods particularly on duck clubs or lands that can be managed specifically for this habitat
- where surface water or extended soil saturation can be provided during winter and spring

Providing seasonal surface water to floodplains and flats will be critical to sustaining existing, and restoring former, bottomland and terrace hardwood forests in the region. Unfortunately, this hydrological aspect is one of the most disrupted parts of the Grand Prairie. Management of greentree reservoirs by farms and duck clubs can play an important role in protecting and restoring these forests in the Grand Prairie. However, greentree forests are very sensitive to management mistakes, and water regimes must emulate natural dynamics to avoid long-term degradation to forest composition and health. New reservoirs built in bottomland and terrace hardwood forests (especially if they are used for irrigation) are not good restoration opportunities, and in fact usually destroy, rather than sustain, remnant forests. Furthermore, rehabilitation of existing irrigation reservoirs that were constructed within bottomland and terrace hardwood forests is unlikely to restore functional systems because of radically altered topography, soils, and water regimes.

Unfortunately, too many attempts to restore bottomland and terrace hardwood forests simply replant trees and do not restore the regulatory hydrology. This activity restores form but not function (King and Keeland 1999, King 2000). Obviously, replanting trees provides ecological benefits that are better than intensively farmed agricultural fields, but where possible, we encourage purposeful restoration of surface hydrology to achieve real ecological function of this system. Sustaining or restoring natural flooding of existing patches of bottomland and terrace hardwood forests should be a high priority within the region and further degradations to the vegetation and hydrology should be avoided. In some locations along the larger rivers and floodplains of the region, active protection or enhancement of existing forests is more important than new restoration. Consequently, conservation actions for bottomland and terrace hardwood forests within the Grand Prairie region should be a mix of protection of critical sites and hydrology, enhancement of regional hydrology in degraded forest patches, and restoration of cleared and drained forests, especially along floodplains within the Demonstration Project area.

## **Specific Considerations Associated with the Grand Prairie Area Demonstration Project**

### **Canals and Ditch Rights-of-way**

About 184 miles of earthen canals are proposed to be built as part of the Grand Prairie Area Demonstration Project to convey irrigation water pumped from the White River. Canals range in bottom width from 5 to 60' and embankments are up to 20' high. Crowns of embankments are 10' wide on each side of the canal and out slopes are 3-3.5 ratios. A 10' easement would be purchased along the outer edges of the embankment slope. Collectively the land area included in the canal (excluding the canal itself) rights-of-way would be about 3,000 acres.

Canal rights-of-way offer some potential to restore some native habitat. However, the proposed right-of-way area is narrow and will have wet and highly drained soils immediately adjacent to canals. Most proposed canals would be built on the former prairie terrace and were prairie grasslands during the 1800s. We believe restoration of prairie grassland on right-of-way lands, especially canal and levee embankments is possible; but may be most successful in areas where prairie previously occurred. Furthermore, where prairie grasses are established in this canal area, regular disturbance of the prairie vegetation will be required to deter encroachment by woody species which will quickly compete with grasses in these sites because soils and water are different from historic conditions. Grazing is not a good option for this disturbance because animals will disrupt embankment slopes and cause erosion. The most appropriate disturbances appear to be periodic burning and mowing.

The narrow linear nature of canals, plus the presence of canal water (that simulates a drainage within a prairie terrace), more closely emulates conditions where slash habitats occurred in the Grand Prairie. We suspect slash vegetation could be quickly established on the inside of levees with relatively minimal effort and cost. However, the presence of trees and shrubs on canal embankments might compromise water conveyance, increase evapotranspiration of the area, and damage levees which are not consistent with irrigation objectives. Similar to slashes, canal areas that traverse former forested habitats are most suited for restoration of forests, but trees might compromise canal structural integrity and water conveyance.

If possible, the best scenario for canal rights-of-way would be to widen the rights-of-way wherever possible to facilitate restoration of all habitats including slash and forest while simultaneously maintaining grasses on canal embankments. Advantages of the canal system are that an interconnected band of habitats could be restored over extensive areas of the Grand Prairie. This is especially important for prairie and bottomland hardwood restoration.

### **On-farm Reservoirs**

An additional 8,859 acres of on-farm storage reservoirs are proposed to be built by the Demonstration Project; the exact number of reservoirs to be constructed is unknown at present. Most reservoirs would be built in existing cropland where adequate watersheds or other surface water sources are available to fill reservoirs. Certain proposals suggest some new reservoirs would be built in drainages and floodplains including some bottomland and terrace hardwood forests.

The construction of additional reservoirs, especially in non-cropland locations, is not helpful to restoration of native habitats in the Grand Prairie region. Additional reservoirs may potentially destroy existing forest and slash area, further divert and reduce overland sheetflow and runoff water, reduce in-stream flows and overbank flooding, and require new ditches and pipelines. Similarly to canal embankments, the levees on reservoirs are narrow and not suited for restoration of forest habitats.

While reservoirs are not useful for restoration of native habitats, they potentially can provide certain resource values to some wildlife species if managed properly. Surface water in reservoirs may provide new habitat for warm-water fisheries and some mud flat and bank habitat for shorebirds and amphibians/reptiles. Attracting these species will require water regimes that maintain suitable water depths for overwintering fish, water drawdowns and reflooding schedules that coincide with seasonal periods when waterbirds are present, and creating saturated mud bank areas for breeding and dormancy periods of amphibians and reptiles. Management plans that provide both irrigation and wildlife needs for these reservoirs must be developed carefully.

### **Conveyance of Water in Existing Streams**

The Demonstration Project proposes to incorporate existing streams into the irrigation water distribution system where possible. About 291 miles of existing streams would be used to deliver water. About 120 low water rock weirs would be constructed in streams to create upstream pools of sufficient depth to allow irrigation withdrawals.

Increased water retention and flow in streams provides some opportunities for enhancement of existing bottomland forests in floodplains and restoration of water regimes and habitats in areas that have been destroyed. The potential for enhancement and restoration of bottomland forested habitats is best where water regimes have been the most degraded and altered because of reduced runoff, in-stream flows, and overbank flooding. Most of the drainages in the Demonstration Project area have such highly degraded water

regimes. While additional surface water in streams is beneficial, benefits depend on when the water is present, how long and deep inundation or flooding occurs, and how flows are restricted by weirs. The natural water regimes of the region included higher flows and flooding from winter through spring, low sustained flows in early summer, and low (sometimes dry) stagnant flow in late summer and early fall. If the Demonstration Project can emulate this regime and restore some winter flooding, then restoration of the most important ecological process in bottomland hardwood forests may be possible in some locations. However, if higher flows and inundation are prolonged into summer, floodplains will be saturated for longer periods and bottomland trees not tolerant of growing-season flooding will die. This latter case of summer flooding would be highly detrimental to existing and newly restored bottomland forests.

#### On-farm Conservation and Winter Flooding of Agricultural Fields

Comprehensive water management plans would be developed as part of the Demonstration Project for each farm in the Project area. The goal of the water management plans would be to increase efficiency of water use and decrease overall surface water needs for agricultural production. Key elements to be incorporated on farms include construction of underground pipelines to minimize losses from evaporation and seepage, tailwater recovery systems, and monitoring of soil moisture. Approximately, 630 miles of new underground pipeline with appurtenances would replace open canals and currently inadequate on-farm distribution systems. An additional 675 miles of tailwater recovery ditches would collect, transport, and store rainfall and tailwater. About 560 water control structures would be built to control runoff rates and provide pools for pumping water back into reservoirs. Approximately 700 pumps or relifts would move water through the tailwater recovery system.

Certain aspects of on-farm conservation measures may assist habitat restoration efforts, while others will have negative effects. Fundamentally, preventing any further depletion of the alluvial aquifer underlying the Grand Prairie is desired by all interest groups. Historically, this aquifer was not directly connected to the surface landscape of the Grand Prairie region except for recharge interchange with the bordering White and Arkansas river floodplains. Depletion of the alluvial aquifer has reversed subsurface water flows and now subsurface water from the White and Arkansas rivers moves toward the prairie terrace and recharges the alluvial aquifer. Where this occurs, surface water regimes in the floodplains and wetlands along the White and Arkansas rivers is reduced and altered (Waldron and

Anderson 1995). This drying of the White River floodplain ultimately will degrade bottomland hardwood forests and animal communities in the entire region. The large corridor of bottomland forest in the White River floodplain is the base connection with Grand Prairie hardwood forests and influences the overall integrity of existing forests. The ultimate success of restoring bottomland forests in the Grand Prairie depends on restoring and maintaining natural seasonal water regimes in drainages of the region, including the White River.

Removing surface ditches and replacing them with underground pipelines may help restore some surface water sheetflow in the Grand Prairie. This restoration of sheetflow will assist efforts to restore prairie grasslands and seasonal herbaceous wetlands. Sheetflow also would provide seasonal water to slashes and floodplains. Countering the potential benefits of pipelines, is the new construction of tailwater recovery ditches and construction of water control structures. These ditches and structures produce opposite effects by diverting surface water flow and make restoration efforts for most habitats more difficult. One potential opportunity associated with tailwater ditches and control structures would be the concurrent construction of off-channel basins that could be restored to seasonal herbaceous wetlands. As stated, these seasonal basins do not have to be large or connected but do require seasonal water regimes that allow germination and establishment of emergent vegetation. Many small seasonal wetlands potentially could be built and managed near water control structures in ditches and canals if seasonal water could be conveyed to them.

The Demonstration Project also proposes to provide enough water through the constructed distribution system to shallowly (12") flood up to 38,529 acres of harvested cropland, mostly rice, during late fall and winter on an average annual basis. Flooding of this land would be voluntary by landowners. Providing surface water to the Grand Prairie landscape during winter emulates historic rainfall and flooding patterns. The trade-off of pumping water onto the region is whether this winter water displaces or reduces natural winter flooding of adjacent habitats in the White River floodplain. Simply redistributing water and trading off winter flooding of adjacent areas is not desirable in ecosystem restoration. If no negative effects occur from redistributing winter water from the White River, then adding new winter water to the Grand Prairie is helpful to restoration efforts and will supplement resources available on agricultural lands (e.g., waste grains and rice field invertebrates).

While winter flooding of agricultural lands in the Grand Prairie will provide important resources, especially food, to some species (primarily waterbirds) this practice does not restore native habitats. We suggest

that part of the water proposed for winter flooding cropland could, instead, be used to restore water regimes in floodplains of the region and help restore slash, herbaceous wetlands, and bottomland and terrace hardwood forested habitats. With the proposed conveyance system, water could be routed to flats and depressions containing terrace hardwood forests, to streams and floodplains to encourage modest overbank flooding and assist restoration of bottomland hardwood forests, and in upper ends of streams where slash habitats occur. If water is routed through the streams and floodplains of the Grand Prairie, releases should occur primarily in late winter and ultimately return to the White River through the drainages. There is some possibility that water could be routed to some harvested rice fields first, and then released to drainages, creating a "conjunctive use." Alternately, water stored in crop fields in winter could be pumped into reservoirs in late winter and be "reused" in spring and summer to partly meet irrigation needs and reduce pumping water from the White River.

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